Developing a Bicycle Monitoring Strategy for Hennepin County:
An Automated Bicycle Counting Program

MURP Capstone Paper

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Executive Summary

Introduction and Background

This report contains a plan for automated monitoring of bicycle traffic on roads in Hennepin County, Minnesota. After completing preliminary experiments with bicycle counting equipment, Hennepin County requested this report to assist staff in designing a comprehensive bicycle monitoring program. Although Hennepin County generally collects project specific information about bicycle volumes, the County does not currently have a systematic bicycle counting program. Previous bicycle counting efforts in the region have been conducted by the City of Minneapolis, Three Rivers Park District, the Metropolitan Council, and the Minnesota Department of Transportation.

Overview

This bicycle monitoring program is composed of two distinct parts. First, we discuss a system-wide bicycle monitoring program, which will allow Hennepin County to obtain detailed information on bicycle volumes all around the road network. This program goes beyond the benchmark counts that are typical of most bicycle counting programs to date and will allow Hennepin County to estimate bicycle volumes using similar data collection and manipulation techniques as they currently use in their vehicle counting program.

The second part of this report discusses a targeted monitoring program. The purpose of this program is to collect detailed bicycle volumes at locations of interest. The targeted monitoring program will supplement the the system-wide monitoring program and allow Hennepin County to collect additional information for specific projects.

Together, these two programs will allow Hennepin County to understand bicycle volume data all around the road network as well as at sites of special interest. Hennepin County requested that this report focus exclusively on the road network. Three Rivers Park District is designing a separate but compatible bicycle monitoring program for trails.

System-Wide Monitoring Program

The purpose of the system-wide monitoring program is to collect bicycle counts on road segments and estimate the average annual daily bicyclists (AADB) and total bicycle miles traveled (BMT) for a network of roads and/or bicycle facilities. A system-wide bicycle monitoring program would yield comparable information for bicycles as is currently collected for vehicles.

A system-wide monitoring program will require both short term and reference sites:

- **Short term** counting sites provide breadth by collecting bicycle data at many locations on the network. Technology is portable and equipment is left out for 48 hours to 7 days.
- **Reference** counting sites provide detailed information about daily variation in bicycle volumes due to weather or holidays. Equipment is permanent and it collects information 24 hours a day, 365 days a year.

Designing a system-wide bicycle monitoring program will require a series of decisions:

Decision 1 - Comprehensiveness: How much of the road network will be measured by the bicycle counting program?

Option 1	Hennepin County right of way outside City of Minneapolis	500 miles
Option 2	Hennepin County right of way with existing bicycle infrastructure outside Minneapolis	130 miles
Option 2a	Hennepin County right of way with existing and planned bicycle facilities outside Minneapolis	265 miles
Option 3	Hennepin County right of way within Minneapolis	82 miles
Option 4	Hennepin County right of way including Minneapolis	582 miles

Decision 2- Integration: Will the bicycle counting program be integrated with the vehicle counting program?

Integration means that bicycles and vehicles are counted at the same time in the same location using the same equipment. Note that further testing of TimeMark equipment (Hennepin County's vehicle counting equipment) will be necessary to determine if it can be used to count bicycles with sufficient accuracy.

Disadvantages	Advantages
• Limited to vehicle counting sites • Count duration limited • Still requires extra equipment • Technical feasibility still needs to be verified	• Use existing vehicle counting equipment to count vehicles and bicycles simultaneously • Minimize equipment and labor costs • Comprehensive coverage

Decision 3 - Number of counting locations: How many count locations are feasible?

There is a trade-off between cost and accuracy. More count locations will provide more comprehensive information about bicycle volumes but will be more expensive. This counting program describes options ranging from 21 counters (covering just Minneapolis) and 600 counters (covering all of Hennepin County).

Decision 4 - Count duration: How long will short term counters be left in the field?

Short term counters are typically left in the field for two to seven days. Although extrapolation accuracy is maximized at seven days, leaving counters in the field for longer periods of time will mean that Hennepin County will have to either count at fewer locations or deploy more equipment. Limiting count duration to two days would allow short term counters to be moved frequently. There is a trade-off between extrapolation accuracy and the cost of the bicycle counting program. Accepting an additional 5% error may be necessary in order to minimize costs and maximize comprehensiveness.

Recommendations

Note: We recommend that Hennepin County and Minneapolis design compatible programs. However, these recommendations assume the programs are not compatible and that Hennepin County will need to count bicycles on roads in Minneapolis.

1. Further testing of TimeMark vehicle counting equipment in 2014: More experimentation is necessary in order to determine whether or not TimeMark counters, which is the equipment Hennepin County uses for vehicular counts, can be used to count bicycles with sufficient accuracy.

2. Pilot program in 2015: Implement a small scale version of the bicycle counting program with 60 short term counting locations (26 locations in suburban Hennepin County and 34 locations in Minneapolis). The pilot program provides an opportunity for Hennepin County to test and refine the program internally on a manageable scale.

3. After 2015, continue building out bicycle counting program to include 94 locations in Minneapolis and 66 locations in suburban Hennepin County. This constitutes the full recommended program and will result in a high level of accuracy in counting.

4. Targeted monitoring in summer 2014: Several locations in Hennepin County are slated for capital improvements or mill and overlay in 2015 or 2016. It is important to collect bicycle counts in summer 2014 so that before and after changes in bicycle volumes can be recognized.

Key locations to count include in targeted counts:

- Washington Avenue (CSAH 152) from Hennepin Ave to 5th Ave S in Minneapolis
- Franklin Ave Bridge (CSAH 5) in Minneapolis
- Penn Avenue South (County Road 32) from Highway 62 to 75th Street in Richfield

Costs

Each decision has implications in terms of labor cost, equipment cost, and accuracy of the bicycle counting program. Cost estimates for the pilot and full recommended programs are provided below. For detailed cost charts, see tables 4 to 7 in the full report.

Pilot Program: (Short term counters)

	Suburban Hennepin County	Minneapolis*
Comprehensiveness	Henn. County ROW with Bicycle Facilities (130 miles)	All Hennepin County ROW (82 Miles)
Integration	Yes	N/A
Density (Count Locations/Mile)	0.2 (26 Counters)	0.4 (34 Counters)
Count Duration	48 hours	48 hours
Count Cycle	2 years	2 years
Cost Estimate**	± $3,100/year	± $7,900/Year

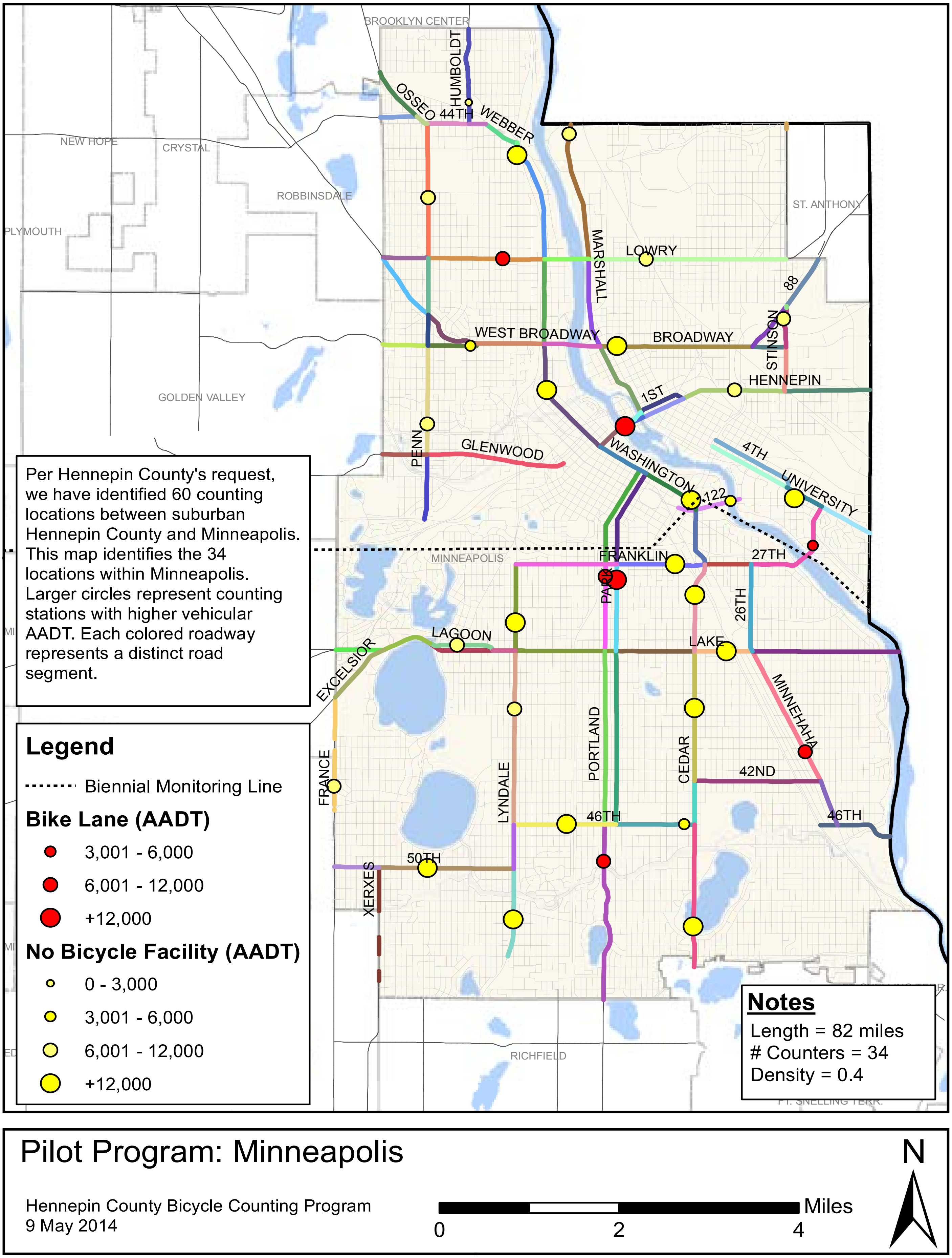
Full Recommended Program (Short term counters)

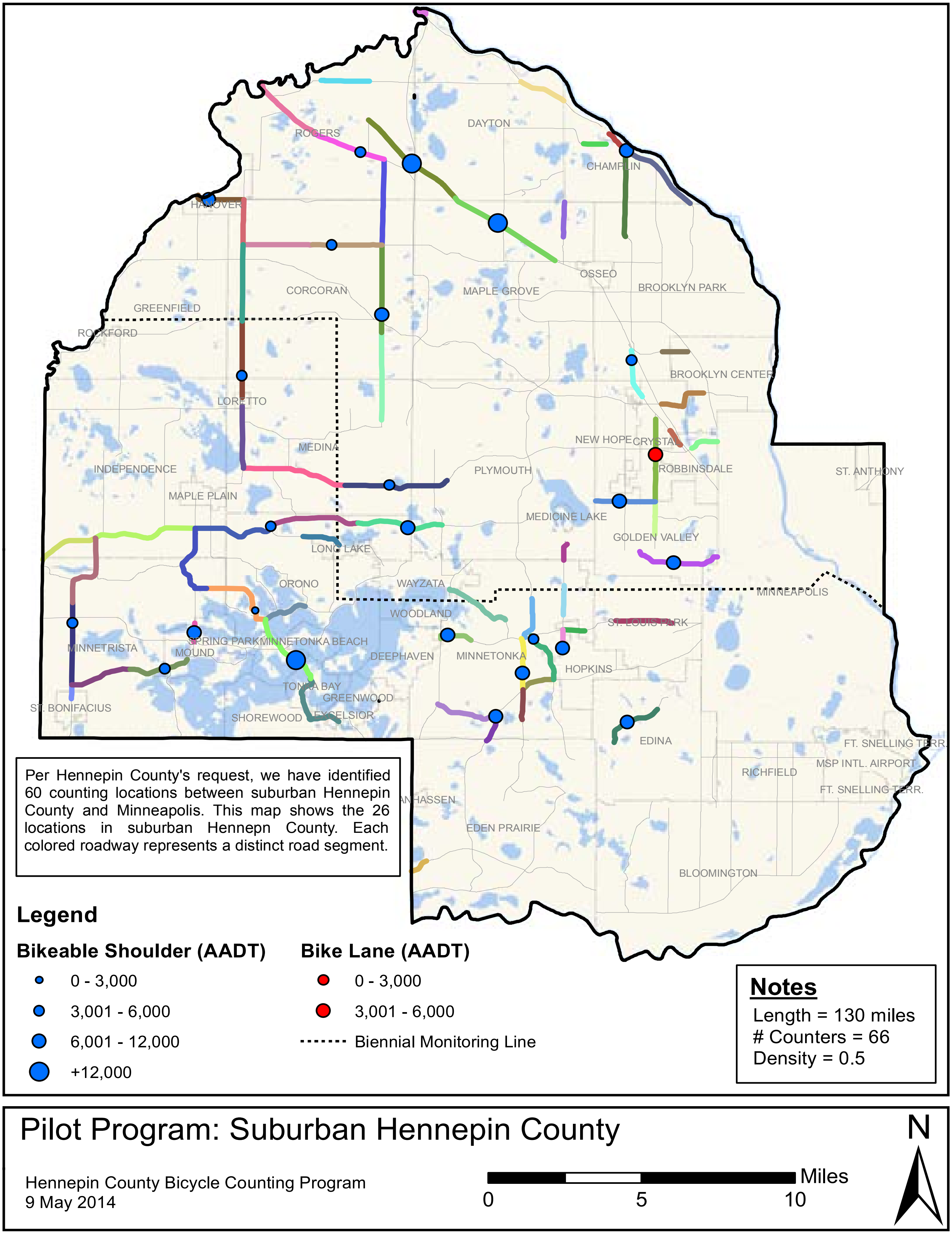
	Suburban Hennepin County	Minneapolis*
Comprehensiveness	Henn. County ROW with Bicycle Facilities (130 miles)	All Hennepin County ROW (82 Miles)
Integration	Yes	N/A
Density (Count Locations/Mile)	0.5 (66 counters)	1.1 (94 counters)
Count Duration	48 hours	48 hours
Count Cycle	2 years	2 years
Cost Estimate**	± $8,000/year	± $18,000/year

Reference Counter Recommendations

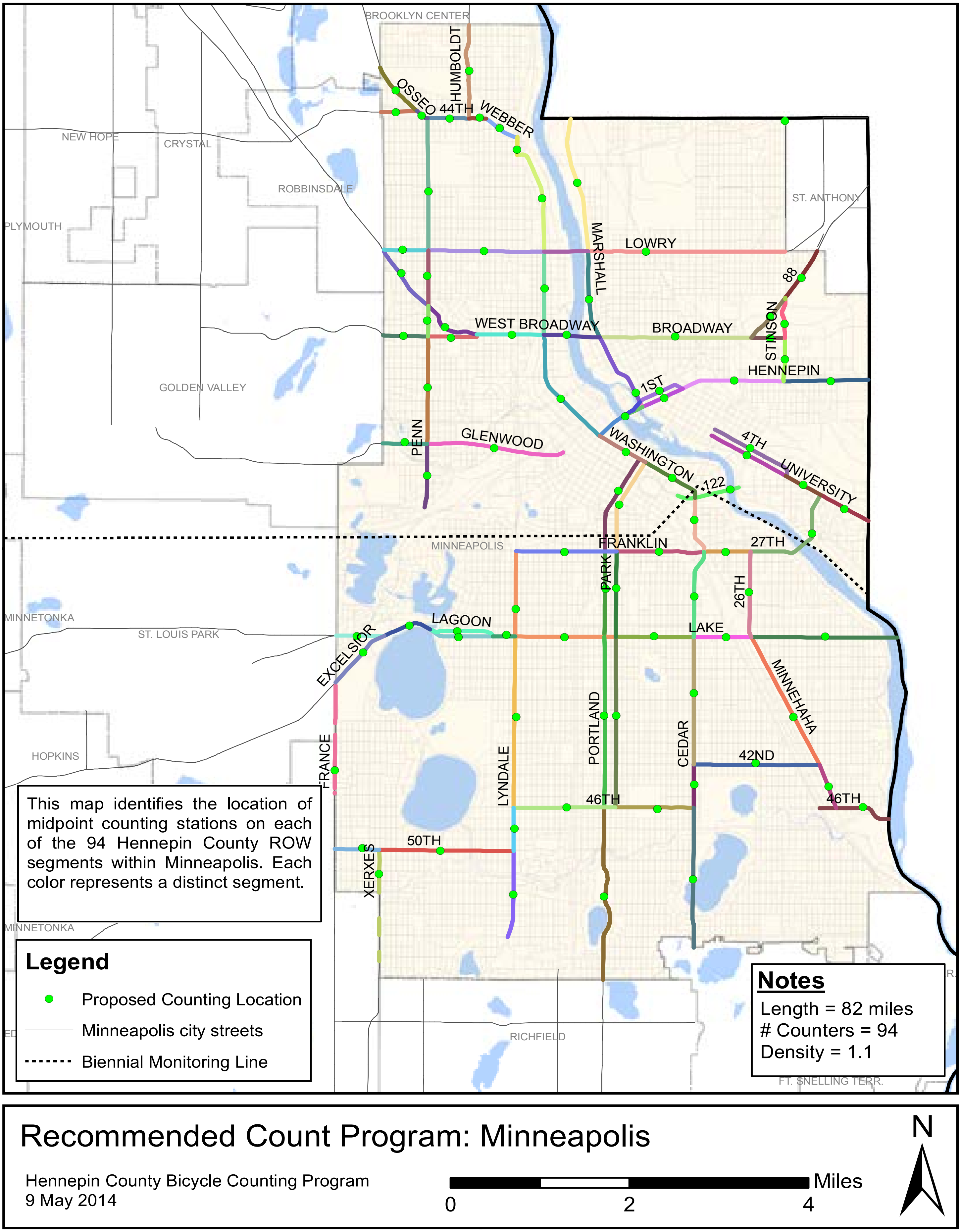
	Pilot Program	Full Recommended Program
Integrated (Yes, No)	Yes	Partial
Total # Reference Locations	2	5
# Integrated	2	2
# Independent	0	3
Installation Cost Estimate	**$1,150**	**$35,005**

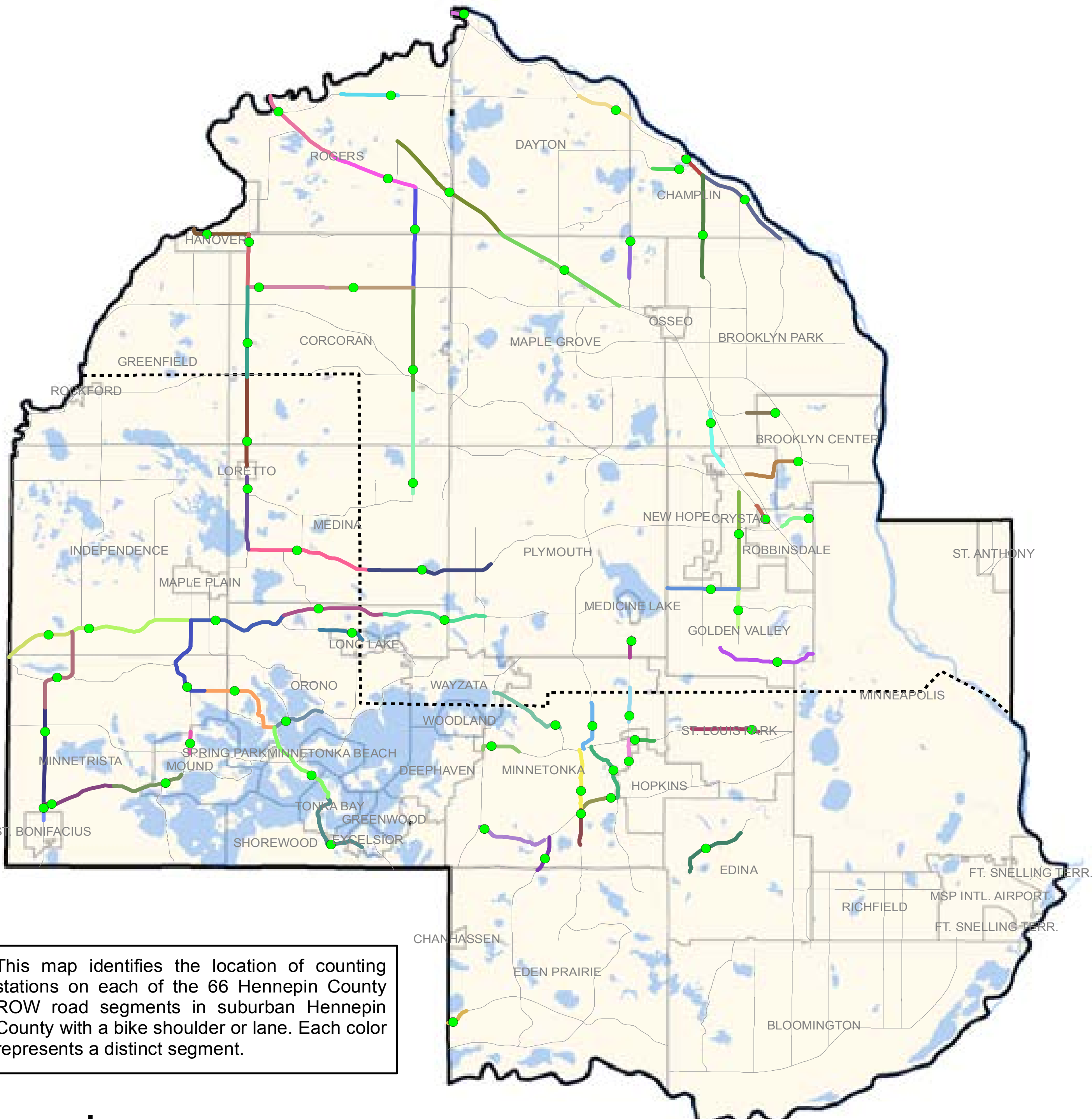
Pilot Program count locations in Minneapolis




ROGERS
DAYTON
CHAMPLIN
HANOVER
CORCORAN
MAPLE GROVE
OSSEO
BROOKLYN PARK
GREENFIELD
ROCKFORD
BROOKLYN CENTER
LORETTO
MEDINA
NEW HOPE
CRYSTAL
ROBBINSDALE
INDEPENDENCE
PLYMOUTH
ST. ANTHONY
MAPLE PLAIN
MEDICINE LAKE
GOLDEN VALLEY
LONG LAKE
ORONO
WAYZATA
MINNEAPOLIS
WOODLAND
ST. LOUIS PARK
SPRING PARK
MINNETONKA BEACH
MINNETRISTA
MOUND
DEEPHAVEN
MINNETONKA
HOPKINS
TONKA BAY
GREENWOOD
ST. BONIFACIUS
SHOREWOOD
EXCELSIOR
EDINA
FT. SNELLING TERR.
MSP INTL. AIRPORT
RICHFIELD
FT. SNELLING TERR.
EDEN PRAIRIE
BLOOMINGTON
Per Hennepin County's request, we have identified 60 counting locations between suburban Hennepin County and Minneapolis. This map shows the 26 locations in suburban Hennepn County. Each colored roadway represents a distinct road segment.
Legend
Bikeable Shoulder (AADT)
0 - 3,000
3,001 - 6,000
6,001 - 12,000
+12,000
Bike Lane (AADT)
0 - 3,000
3,001 - 6,000
Biennial Monitoring Line
Notes
Length = 130 miles
# Counters = 66
Density = 0.5
Pilot Program: Suburban Hennepin County
Hennepin County Bicycle Counting Program
9 May 2014
0
5
10
Miles
N

Recommended Count Locations in Minneapolis





This map identifies the location of counting stations on each of the 66 Hennepin County ROW road segments in suburban Hennepin County with a bike shoulder or lane. Each color represents a distinct segment.

Legend

- Proposed Counting Locations
- Hennepin County Roads
- Biennial Monitoring Line

Notes

Length = 130 miles
# Counters = 66
Density = 0.5

Recommended Count Program: Suburban Hennepin County

Hennepin County Bicycle Counting Program
9 May 2014

0 5 10 Miles

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CONTENTS

I. INTRODUCTION

In recent years, bicycling as a mode of transportation has gained increasing amounts of attention in the United States because of its potential to alleviate a number of diverse and significant problems, from congestion and air pollution to obesity. The consensus in both academic and popular literature is that bicycling has increased in popularity over the last 10 to 20 years. However, there is limited additional information about the nature of this increase. While a few cities collect data on bicycle and pedestrian traffic (eg. Boulder, Colorado has been doing automated counts since 1998; Minneapolis, Minnesota has been doing manual counts since 2007), most cities do not systematically collect this information. Information that is collected is often sporadic and of varying quality and type.

In 2013 for the first time, the Federal Highway Administration's Traffic Monitoring Guide (TMG) included a chapter on monitoring non-motorized traffic. This chapter reflects a growing recognition among transportation professionals that data on bicycle and pedestrian traffic is needed. Vehicle counts have long been the foundation of transportation planning for cars, heavily influencing many decisions, from distribution of federal funding to the allocation of right-of-way space. A systematic, comprehensive understanding of bicycle traffic is needed to inform research on bicycle travel and to help engineers, planners and policy makers understand and effectively plan for this vital mode of transportation.

I.1. Overview

This bicycle monitoring program is composed of two distinct parts. First, we discuss a system-wide bicycle monitoring program (Sections II, III & IV), which will allow Hennepin County to obtain comprehensive and detailed information on bicycle volumes all around the road network. This program goes beyond the benchmark counts that are typical of most bicycle counting programs and will allow Hennepin County in estimating bicycle volumes using methods similar to those currently used in most vehicle counting programs.

The second part of this report discusses a targeted monitoring program (Section V). The purpose of this program is to collect detailed bicycle volumes at locations of interest. The targeted monitoring program will supplement the the system-wide monitoring program and assist Hennepin County in collecting additional information at locations where it is needed.

Together, these two programs will allow Hennepin County to understand bicycle volumes across the road network as well as at sites of special interest or concern. Per our conversations with the County, the program focuses exclusively on the road network. However, the program is flexible and may be modified to include future planned facilities and/or bicycle trails.

Geographic Context

Hennepin County is located in south-eastern Minnesota and, with a population of 1.2 million people, is the most populous county in the state. Minneapolis, Minnesota's largest city, falls within Hennepin County. As of 2013, Hennepin County's transportation department maintains almost 600 miles of roads, including over 130 miles of bike facilities (including bike lanes and 5 foot shoulders). Additionally, Hennepin County partners with Three Rivers Park District in the maintainance and expansion of over 100 miles of off-street trails for bicycles and pedestrians.

This bicycle counting plan concerns only Hennepin County roads; it does not address off-road trails or roads that are maintained by the cities within Hennepin County. Three Rivers Park District is developing a separate but compatible bicycle counting plan for off-road trails (see Figure 1).

I.2. Bicycle Count Uses

In speaking with Hennepin County staff and other bicycle and pedestrian professionals in the region, the following primary uses for bicycle counting data were identified:

1. Calculate crash and injury rates: To calculate crash rates, the County needs to know how many bicyclists are using a given road and/or the road system. Municipalities use police reports to track the number and nature of crashes. However, without information about bicycle volumes, it is impossible to calculate an accurate crash rate (number of crashes divided by number of bicyclists on that road over a certain period of time; often expressed as number of crashes per 1000 bicyclists, per unit time). It is important to calculate crash rates because looking only at the number of crashes can be misleading; the number of crashes could increase while the rate of crashes is actually decreasing.

Crash rates can be calculated at a certain location or system-wide. This information has the potential to help the County decide how and where to target safety campaigns or infrastructure changes. Hennepin County staff interviewed by the authors of this report identified crash rate information as a key priority for information to be gleaned from a bicycle counting plan.

2. Measure progress towards benchmarks and goals: Measuring progress towards goals is another key application of bicycle counting data identified by Hennepin County staff. Hennepin County will be releasing a bicycle master plan in late 2014 and bicycle count data will allow the County to track progress towards goals identified in this plan. For example, one goal of the bicycle plan will be to double bicycling in Hennepin County by 2030. Bicycle counting data will allow the county to accurately assess whether current policies and practices are successful in achieving that goal.

3. Determine relative use & traffic control: Bicycle count data will allow Hennepin County to compare bicycle volumes to vehicle volumes on any given road, and to compare bicycle traffic on different parts of the network. This could help to determine traffic signage and signalization at intersections. Bicycle and vehicle counting data have already been used to change the priority of signalization at the intersection of the Midtown Greenway bicycle trail and 5th Avenue S. At this intersection, bicycle volume was demonstrated to be greater than vehicle volume, so stop signs were changed to face the street rather than the bike path (see Appendix E).

4. Inform infrastructure projects: Hennepin County staff currently plan infrastructure projects with the goal of creating a comprehensive network of safe bicycle routes. Bicycle count data would allow staff to be informed when they design these projects. Count data could help staff explain to communities or elected officials why a bicycle facility is or is not necessary in a given location. It could also help describe to communities the impact of having a bicycle facility on a given street by allowing staff to estimate traffic volume in a certain location.

5. Evaluate trends over time: Bicycle count data will allow Hennepin County to accurately measure how bicycle traffic is changing over time. This bicycle counting plan will explain techniques to determine an accurate estimate of annual average daily bicycles (AADB). Over time, this will enable the County to track whether bicycle use is increasing or decreasing overall, as well as to analyze how bicycle traffic patterns change over time. These patterns will be especially important to identify after an infrastructure improvement has taken place.

6. Identify temporal and spatial usage patterns: While manual counts are often limited to two hours in duration, an automated bicycle count program will provide information about peak usage patterns on bicycle facilities. Bicycle use can be variable and heavily influenced by factors such as weather and pavement conditions. Data collected continuously for days or months is needed to increase understanding of these patterns.

There are also a variety of auxiliary uses for bicycle counts. Information about bicycle miles travelled is useful in a public health setting because it can provide information about physical activity levels or of the effectiveness of an education and encouragement campaign. Before-and-after data around a new bicycle facility can provide information for a cost/benefit analysis or a performance analysis. This would be especially useful in pilot projects when innovative treatments are being tested. Continuous counts can provide information about how bicycle usage varies with seasonal and daily weather patterns.

It is highly likely that other uses for bicycle counts will arise over time. This bicycle counting program is designed to provide counting data that is flexible in its application and that will improve in accuracy over time.

I.3. Literature Review

Although comprehensive, automated bicycle counting programs are rare in the United States, there is a growing body of academic research on bicycle counting strategies. The procedure recommended in this bicycle counting plan is based on Chapter 4 of the 2013 Federal Highway Administration's Traffic Monitoring Guide (TMG). The TMG provides summary descriptions of most bicycle and pedestrian counting technologies, methods to account for time of day, weather, and seasonal variation, recommendations for data processing, and recommendations for useful summary statistics.

The TMG recommends use of day-of-week and seasonal adjustment factors to account for variability in bicycle volumes and allow the calculation of average annual daily bicycles (AADB) and total annual bicycle miles traveled (BMT). Since the release of the 2013 TMG, further research by Hankey, Lindsey, and Marshall at the University of Minnesota (2014) has shown that "day-of-year" scaling factors provide better accuracy than day-of-week or seasonal adjustment factors (Miranda-Moreno et al., 2013). Their paper also provides guidance on the length of time needed for short term counts. The results of this research suggests that improvements in AADB estimation accuracy are insignificant as short-term count durations extend beyond 7-days (see Section II.3.5). Lindsey, Nordback, and Figliozzi (2013) summarize bicycle and pedestrian counting efforts to-date in Colorado, Minnesota, and Oregon.

A major challenge to bicycle counting is that it is highly variable. Researchers at McGill University in Montreal offer a strategy for classifying bicyclists to improve counting accuracy (Miranda-Moreno et al., 2013). They used automated counts from 40 locations in Montreal, San Francisco, Ottawa, Portland, and Vancouver to look at hourly and weekly traffic patterns at different locations and found that bicycle volume patterns at each location could be classified as utilitarian, mixed utilitarian, recreational, or mixed recreational (see Table 1). Categorizing counting lo-

***Table 1**: Summary of bicycle use-types (Miranda-Moreno et al., 2013)*

Utilitarian	Usage is higher on weekdays than weekends and higher during the morning rush hour than midday (morning and evening peaks in usage).
Recreational	Usage is higher on weekends and higher at midday than during the morning peak.
Mixed-Utilitarian	Usage is mixed but tends towards utilitarian uses.
Mixed-Recreational	Usage is mixed but tends towards recreational uses.

cations is likely to improve extrapolation accuracy of short term counts.

There is a wealth of research detailing the public health and environmental benefits of bicycling as a mode of transportation and of the need for accurate count information. Saelensminde (2004) offers a cost benefit analysis of bicycle and pedestrian facilities in three Norwegian cities and concludes that benefits are 4-5 times greater than costs. Gotschi (2011) offers a similar analysis of Portland, Oregon, focusing on the public health benefits specifically. Finally, Cavill (2009) offers a review of 16 economic cost/benefit analysis studies and concludes that more data and more transparent methodologies are needed to make a full assessment of cost and benefits.

This bicycle monitoring plan is based on best practices and techniques identified in the literature referenced above.

II. SYSTEM-WIDE MONITORING PROGRAM

II.1. Purpose

The purpose of a system-wide bicycle monitoring program is to collect bicycle counts on road segments and estimate the average annual daily bicyclists (AADB) and total bicycle miles travelled (BMT) for a network of roads and/or bicycle facilities. Hennepin County currently collects data on the number of motorized vehicles on each road on their network and estimates average annual daily traffic (AADT) and vehicle miles traveled (VMT). A system-wide bicycle monitoring program would yield comparable information for bicycles.

II.2. Program Overview

The development of a system-wide monotoring program requires a series of decisions regarding five seperate factors. These factors include comprehensiveness, integration with vehicle counts, density of counting sites, duration of counting sites, and length of count cycle. Section II.3 explores each of the decisions in detail. Figure 1 on the next page provides an overview of these decisions in the form of a decision tree. The purpose of this section is to explain each parameter, including how it was determined and how it influences the decision making process.

In Section II.4 we summarize the implications of each decision in terms of cost. Lastly, in Section II.5 we include a discussion of how each decisions influences the accuracy of the results.

II.3. Program Design Parameters

Decisions regarding implementation of the bicycle counting program should be based on a consideration of the following parameters:

II.3.1. Comprehensiveness

Comprehensiveness describes how much of the geographic network is measured by the counting program. In this report, comprehensiveness is described by the number of miles covered by each option. Comprehensiveness options include:

- **Option 1**: Hennepin County right of way outside city of Minneapolis = 500 miles
- **Option 2**: Hennepin County right of way with existing bicycle infrastructure outside Minneapolis = 130 miles
- **Option 2a**: Hennepin County right of way with existing and planned bicycle facilities outside Minneapolis = 265 miles
- **Option 3:** Hennepin County right of way within Minneapolis = 82 miles

Refer to Figure 3 for a map illustrating these options. Note that the options above focus only on on-street bicycle facilities. This was a decision based on conversation with Hennepin County staff. Refer to Figure 1 for a summary of off-street bicycle counting efforts by the Three Rivers Park District.

As shown in the decision tree (Figure 2), a key decision is how to address bicycle counts in Minneapolis. Vehicle counts on Hennepin County right of way in Minneapolis are conducted by the City of Minneapolis using the Peek ADR 1000 Traffic Counter which at this time has not been proven capable of counting bicycles. Minneapolis recently purchased bicycle specific counting equipment and will be testing it at a number of locations in 2014. If Minneapolis designs a bicycle counting program that is compatible with Hennepin County's bicycle counting program (i.e. it can provide information on AABT and BMT for network segments), bicycle counting on Hennepin County right of

***Figure 1**: Summary of Three Rivers Park Distict counting efforts*

Integration with Three Rivers Park District

Three Rivers Park District is responsible for building and maintaining a large proportion of the off-street trails in Hennepin County. While this counting program provides guidance only for on-street bicycle facilities, parallel counting efforts on Three Rivers trails will be crucial in order to obtain a full picture of bicycle volumes in Hennepin County.

A Three Rivers bicycle and pedestrian counting plan is also in progress which will be compatible with the plan proposed here for Hennepin County because it will use automated counting technology and segmentation techniques to provide information about AABT and BMT. This will allow Hennepin County to sum BMT for the road network and the trail network in order to track progress towards benchmark goals. Additionally, AABT information for the road and trail network could be combined onto one map to provide comprehensive information about bicycle volumes at different points on the network and over time.

***Figure 2**: System-wide program decision tree*

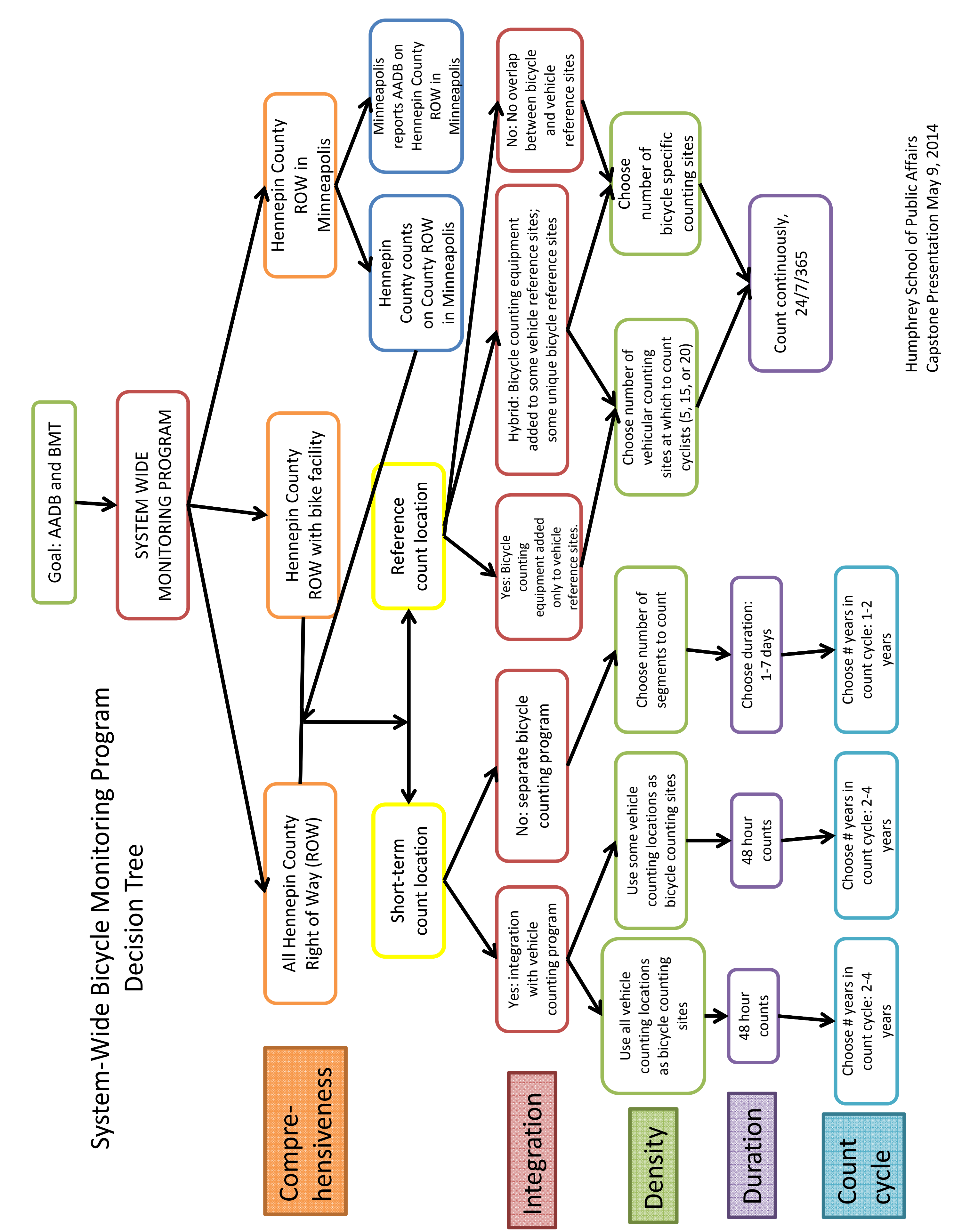
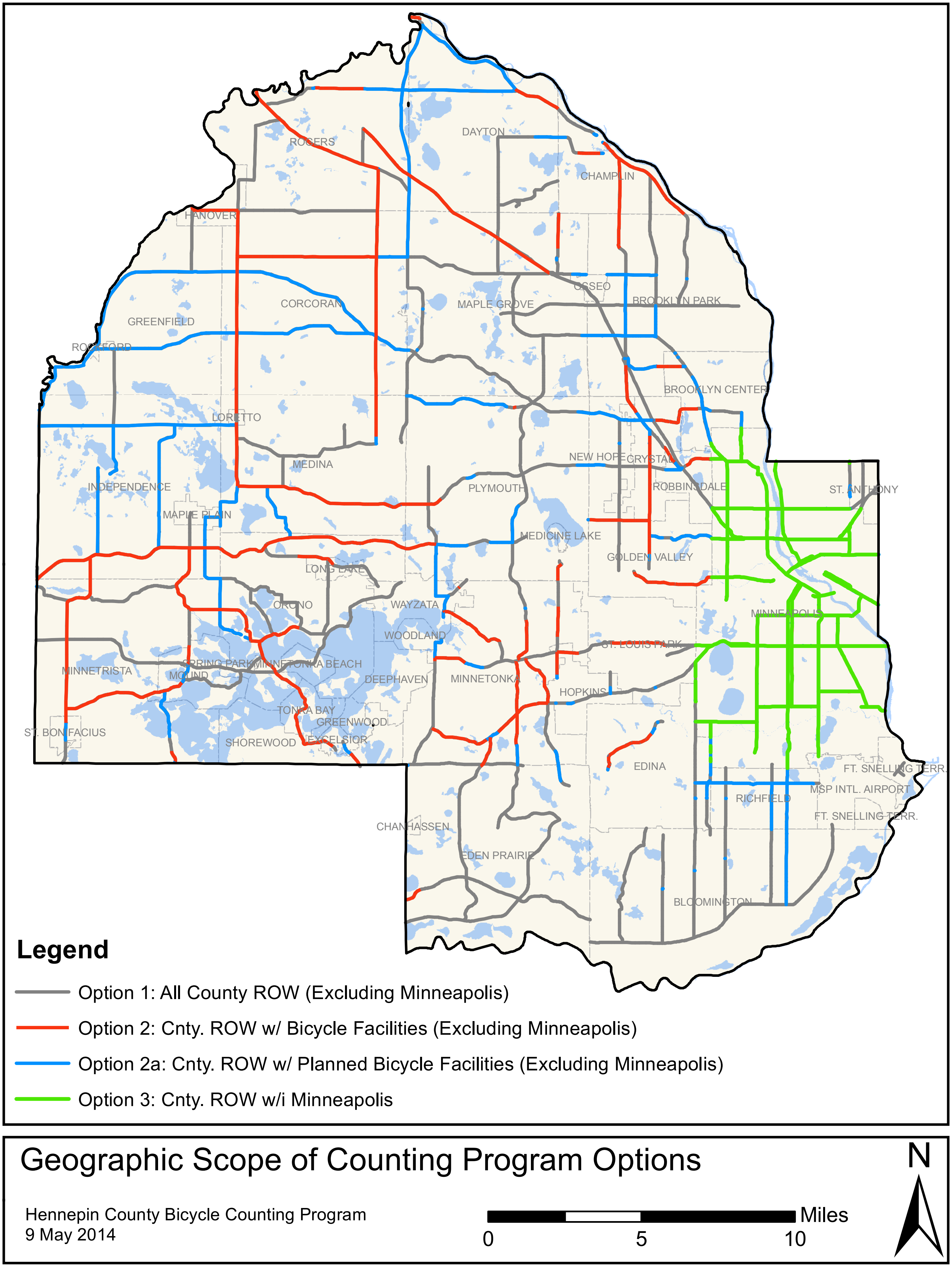


Figure 3: *Map of the comprehensiveness options*



way in Minneapolis could be conducted by Minneapolis and reported to Hennepin County. If Minneapolis' bicycle counting program is not compatible, Hennepin County may choose to count bicycles on County right of way in Minneapolis.

II.3.2. Short Term and Reference Counting Sites

For this bicycle counting plan, both short term and reference counting sites are needed. Short and long term counting locations differ significantly in purpose, technology, and location criteria.

Short term counting locations are sites where counting equipment is temporarily installed and data is collected for a short time-span (1 to 7 days). These sites:

- provide breadth by collecting bicycle data at many locations on the network.
- count the number of cyclists that pass by a specific location.
- use infrared or pneumatic tube counting technology. Hennepin County uses TimeMark NT tube counters for short term vehicular counts.
- cannot be used during the winter months due to snow plows.

Reference counting locations are sites where counting equipment is permanently installed and data is collected 24 hours a day, 365 days a year. These sites:

- provide information that can be used to calculate day-of-year factors, which adjust short-term counts to account for daily variation in bicycle volumes (see Figure 5).
- typically use equipment that is embedded in the ground, such as inductive loops (in-ground wires that detect metal objects) or Sensys pucks (an in-ground wireless vehicle detection system).
- are installed under the pavement and can collect data in all seasons, regardless of snow and ice.

Bicycle traffic is highly variable and is easily influenced by factors such as weather and holidays, so counts collected on any given day may or may not be representative of a typical day at that site.

Data from reference sites provides information on how bicycle travel varies by weather, season, day of the week, time-of-day and more. This data is used to calculate a day-of-year factor that is applied to short-term data in order to calculate AADB and BMT. See Section IV.3 for a summary.

II.3.3. Integration

Integration describes the degree to which the existing vehicle counting program and the future bicycle counting program overlap. This report presents a spectrum of options from complete integration, in which all bicycle counting sites are co-located with vehicle counting sites, to complete separation, in which bicycle counting sites are installed without regard to existing vehicle counting sites. See Tables 2 and 3 for a summary of the advantages and disadvantages of integrating short-term and reference count locations. The bicycle counting program will most likely be a combination of those two extremes, with some integrated sites and some bicycle specific sites.

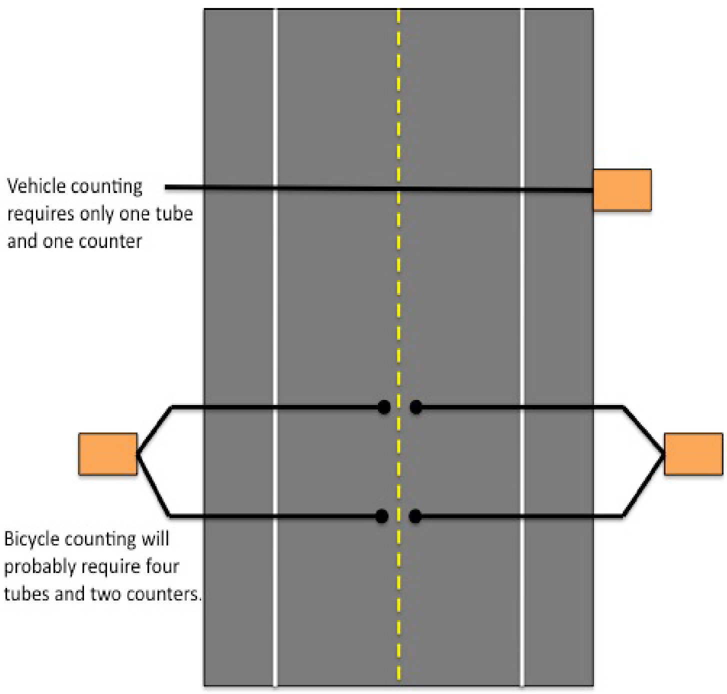
Table 2*: Advantages and disadvantages of integration with short-term vehicular count locations*

Advantages	Disadvantages
• Minimal equipment purchase required. • Set-up and take-down of equipment can be integrated into existing vehicle counting routines. • Integration with existing labor in terms of data collection, storage, and manipulation. • Allows the collection of bicycle data at a large number of locations due to the wide coverage of vehicle counting locations. • Current research by Hennepin County is being conducted to determine the accuracy of TimeMark pneumatic tube technology in classifying both vehicles and bicycles using the same counting location and device. Similar tests have been done in Boulder County, Colorado using Metro Count technology. These devices are similar to TimeMark devices and have successfully classified bicycles and vehicles.	• Count duration limited to 24 hours (see Duration section below). • Potential reduction in extrapolation accuracy (see Duration below). • While vehicle counts can be conducted with one pneumatic tube, bicycle counts will require two parallel pneumatic tubes for classification purposes. • Counting bicycles may also require one counter (2 pneumatic tubes) for each direction of traffic, requiring one side of the tubes to be hammered into the road at the center line as shown in Figure 4. • Limited to vehicle counting locations which may not be ideal for counting bicycles. • Counting locations may not be representative of the segment they cover.

Table 3: *Advantages and disadvantages of integration with reference vehicular count locations*

Advantages	Disadvantages
• Highly cost efficient when using the Sensys puck technology-- additional pucks can be installed in the ground and use the same above ground receiver as the vehicle counters. • Requires minimal additional labor in installation and maintenance.	• A separate bicycle counting program could ensure that reference sites are chosen based on specific bicycle counting needs.

Figure 4: *Vehicle counter configuration vs. bicycle and vehicle classification configuraton*



II.3.4. Density

Density describes the average number of count locations per mile. This concept is most important in terms of implementation costs because it directly relates to the number of count locations and counters needed for a particular program.

It is important to note that density is not a decision in and of itself. Density is related to the segmentation process (see Section IV.1), which is the process of identifying segments over which bicycle traffic is consistent. Once segmentation is complete, density is calculated by dividing the number of segments by the miles of roadway within a the chosen network. One count location should be identified to represent each segment. As bicycle data is collected, it is likely that some adjacent segments may need to be consolidated or split to better represent bicycle traffi. These adjustements will result in different densities in the future. Final segment lengths may vary significantly.

Density of short term counting sites

Densities in this program range from 1.2 counters per mile (this is the density of the existing vehicular count program) to 0.25 counters per mile. For the sake of comparison, the following options were considered for the density decision. This does not represent a comprehensive list of potential densities.

- 1.2 counters per mile. If every existing vehicle counting location were used also as a bicycle counting location, the density would be 600 counters / 500 miles.
- 0.50 counters per mile. If 250 vehicle counters are used also as bicycle counters, density would be 250 counters / 500 miles.
- 0.25 counters per mile. If 125 vehicle counters are used also as bicycle counters, density would be 125 counters / 500 miles.

B. Density of reference sites

For reference sites to be useful in extrapolation and lead to accurate AADB estimates, they must be representative of all known traffic patterns. Bicycle traffic patterns are often not known until short duration counts are completed. Best practice is to locate reference sites on facilities that match each of the four use-types listed in Table 1.

Important criteria for reference sites:

- A robust reference site network will include at least five reference sites in each of the above four groups
- The most important criteria for reference sites are the degree to which they cover all of the categories above.
- When each category is monitored by five reference sites, accuracy in extrapolation will be maximized.
- If all categories are monitored by less than five reference sites, one universal adjustment factor can be used. In this situation, AADB and BMT will be less accurate. Studies have not yet been done to quantify how much accuracy will be gained by calculating unique adjustment factors for each of the four categories above.

II.3.5. Count Duration

Count duration describes the length of time counting information is collected. Reference sites collect data at all times, so further discussion of duration is not necessary for reference sites. Short term bicycle counts are typically collected for 24 hours to 7 days.

As Figure 5 demonstrates, as the number of count days increases, mean absolute error in AADB estimates decreases. After 7 days, there is a negligible benefit in terms of accuracy. We recommend that short term counts be collected for a minimum of 1 day and for a maximum of 7 days. Although 7 day counts would result in more accurate estimates of AADB, conducting counts for 1 or 2-day count would allow equipment to be moved more often, leading either to a higher density of count locations or a more comprehensive count. Conducting shorter counts would also reduce the amount of equipment needed on bicycle counting projects.

It is valuable to note that count duration can vary within a single count program. For example, it may be worth using a 1 or 2-day count duration for most short-term count locations for the sake of efficiency while using a 7-day duration for specific locations where accuracy is of greater importance. Refer to Appendix B for instructions on analyzing data.

II.3.6. Count Cycle

Count cycle describes how many years it takes to collect data for every short-term location in the program. Hennepin County is currently on a 2 year cycle for vehicle counts because half of all short-term counting locations are counted each year.

This program presents options for count cycles ranging from 1 year to 4 years. Count cycles of longer than 4 years may not capture important changes in bicycle volumes that could have transportation planning implications.

II.4. Cost Summary

Each of the decisions described above (comprehensiveness, integration, density, count duration and count cycle) has implications in terms of labor cost and equipment cost. Tables 5-8 summarize these decisions and their cost implications. This section provides a brief description of how the tables were developed. For a detailed list of cost

***Figure 5**: AADB estimation error as it relates to count duration. The new scaling method refers to the day-of-year scaling method, which we recommend (Hankey et al., 2014)*

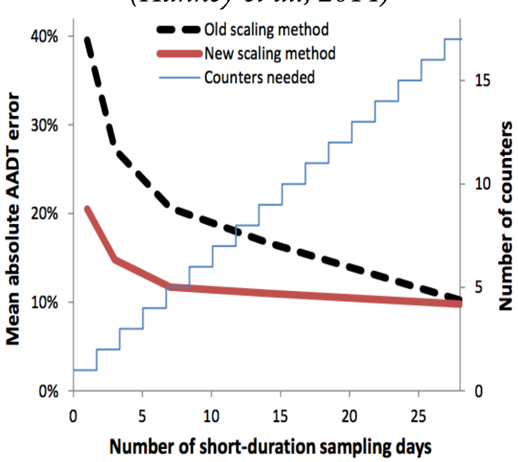


FIGURE 2 Mean absolute AADT estimation error using the standard (black-dashed) and new scaling methods (red-solid). Number of counters needed to complete the design scenario (7-month sampling campaign) is shown in blue.

assumptions and calculations, refer to Appendix B.

II.4.1. Short term counting site costs

The cost tables below are organized to reflect the program decisions established in the Decision Tree (Figure 2). Furthermore, a table was created for each of the comprehensiveness options (Options 1, 2, 2a & 3). Lines 1-6 on each table list these decisions and the options associated with each of them. This is not meant to be a comprehensive list of options, but it is meant to provide a helpful means of comparison between choices.

Lines 7-10 on each table summarize the implications of the options above in terms of count locations and material requirements. For example, if Hennepin County elected to make the decisions shown in Table 4, then we would know from lines 7-10 in Table 6 that the selected program includes 130 total count locations, 65 annual count location, and the need to purchase at least 2 new counters. From this it is possible to understand the scope of a particular program option. In the example used here, Hennepin County would be counting 130 miles of suburban Hennepin County roadway with 65 biennial count locations. The

***Table 4:** Example of decision process*

	Suburban Hennepin County
Comprehensiveness	Henn. County ROW with Bicycle Facilities (130 miles)
Integration	No
Density (Count Locations/Mile)	1.0 (130 counters)
Count Duration	48 hours
Count Cycle	2 years

***Figure 6**: Day-of-year factor scaling method*

Day of Year Factors

Hankey, Lindsey, and Marshall (2014) recommend replacing the traditional day-of-week and month-of-year factors with a new multiplier called a day-of-year (DOY) factor. At the end of the year, information from all reference sites around the network is used to create a unique multiplier for each day of the year. DOY factors are highly specific and only apply to one single day of one single year. When applied to short term counts, the day of year factor adjusts for daily variability in bicycle volumes due to weather or holidays, allowing high accuracy in using short term counts (as short as 48 hours) to calculate AADB.

Table 5: *Cost estimates for Option 1 scenarios*

Line 1		**Option 1: All County ROW in Suburban Hennepin County**																							
Line 2	**Comprehensiveness (miles)**	500 miles																							
Line 3	**Integrated?**	Yes						No																	
Line 4	**Density (count locations/mile)**	1.2 (#/mile)		0.5 (#/mile)		0.25 (#/miles)		1 (#/miles)						0.5 (#/miles)						0.25 (#/miles)					
Line 5	**Count Duration (days)**	1 day		1 day		1 day		1 day		4 days		7 days		1 days		4 days		7 days		1 days		4 days		7 days	
Line 6	**Count Cycle in Years**	2 years	4 years	2 years	4 years	2 years	4 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years
Line 7	Total Count Locations	600	600	250	250	100	100	500	500	500	500	500	500	250	250	250	250	250	250	125	125	125	125	125	125
Line 8	Annual Count Locations	300	150	125	63	50	25	500	250	500	250	500	250	250	125	250	125	250	125	125	63	125	63	125	63
Line 9	Locations from 1 counter in 1 season	40	40	40	40	40	40	40	40	24	24	15	15	40	40	24	24	15	15	40	40	24	24	15	15
Line 10	Additional Counters Requirec	8	4	4	2	2	1	13	7	21	11	34	17	7	4	11	6	17	9	4	2	6	3	9	5
Line 11	*Labor Cost Summary*																								
Line 12	Time required (hours)	750	375	313	156	125	63	2,333	1,167	2,333	1,167	2,333	1,167	1,167	583	1,167	583	1,167	583	583	292	583	292	583	292
Line 13	*Labor Cost Per Year*	$56,250	$28,125	$23,438	$11,719	$9,375	$4,688	$140,000	$70,000	$140,000	$70,000	$140,000	$70,000	$70,000	$35,000	$70,000	$35,000	$70,000	$35,000	$35,000	$17,500	$35,000	$17,500	$35,000	$17,500
Line 14	*Material Cost Summary*																								
Line 15	Tube Depreciation Per Year	$160	$80	$80	$40	$40	$20	$520	$280	$840	$440	$1,360	$680	$280	$160	$440	$240	$680	$360	$160	$80	$240	$120	$360	$200
Line 16	Counter Depreciation Per Year	$1,120	$560	$560	$280	$280	$140	$1,820	$980	$2,940	$1,540	$4,760	$2,380	$980	$560	$1,540	$840	$2,380	$1,260	$560	$280	$840	$420	$1,260	$700
Line 17	Vehicle Costs Per Year	$0	$0	$0	$0	$0	$0	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600
Line 18	Misc Costs Per Year	$0	$0	$0	$0	$0	$0	$1,000	$500	$1,000	$500	$1,000	$500	$500	$250	$500	$250	$500	$250	$250	$125	$250	$125	$250	$125
Line 19	*Material Costs Per year*	$1,280	$640	$640	$320	$320	$160	$4,940	$3,360	$6,380	$4,080	$8,720	$5,160	$3,360	$2,570	$4,080	$2,930	$5,160	$3,470	$2,570	$2,085	$2,930	$2,265	$3,470	$2,625
Line 20	20% Contingency	$11,506	$5,753	$4,816	$2,408	$1,939	$970	$28,988	$14,672	$29,276	$14,816	$29,744	$15,032	$14,672	$7,514	$14,816	$7,586	$15,032	$7,694	$7,514	$3,917	$7,586	$3,953	$7,694	$4,025
Line 21	**Cost**	**$69,000**	**$34,500**	**$28,900**	**$14,400**	**$11,600**	**$5,800**	**$173,900**	**$88,000**	**$175,700**	**$88,900**	**$178,500**	**$90,200**	**$88,000**	**$45,100**	**$88,900**	**$45,500**	**$90,200**	**$46,200**	**$45,100**	**$23,500**	**$45,500**	**$23,700**	**$46,200**	**$24,200**

Table 6: *Cost estimates for Option 2 scenarios*

Line 1		**Option 2: County ROW with Bicycle Facilities in Suburban Hennepin County**																							
Line 2	**Comprehensiveness (miles)**	130 miles																							
Line 3	**Integrated?**	Yes						No																	
Line 4	**Density (count locations/mile)**	1.1 (#/mile)		0.5 (#/mile)		0.25 (#/miles)		1 (#/miles)						0.5 (#/miles)						0.25 (#/miles)					
Line 5	**Count Duration (days)**	1 day		1 day		1 day		1 day		4 days		7 days		1 days		4 days		7 days		1 days		4 days		7 days	
Line 6	**Count Cycle in Years**	2 years	4 years	2 years	4 years	2 years	4 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years
Line 7	Total Count Locations	156	156	65	65	26	26	130	130	130	130	130	130	65	65	65	65	65	65	32.5	32.5	32.5	32.5	32.5	32.5
Line 8	Annual Count Locations	78	39	33	16	13	7	130	65	130	65	130	65	65	33	65	33	65	33	33	16	33	16	33	16
Line 9	Locations from 1 counter in 1 season	40	40	40	40	40	40	40	40	24	24	15	15	40	40	24	24	15	15	40	40	24	24	15	15
Line 10	Additional Counters Requirec	2	1	1	1	1	1	4	2	6	3	9	5	2	1	3	2	5	3	1	1	2	1	3	2
Line 11	*Labor Cost Summary*																								
Line 12	Time required (hours)	195	98	81	41	33	16	607	303	607	303	607	303	303	152	303	152	303	152	152	76	152	76	152	76
Line 13	*Labor Cost Per Year*	$14,625	$7,313	$6,094	$3,047	$2,438	$1,219	$36,400	$18,200	$36,400	$18,200	$36,400	$18,200	$18,200	$9,100	$18,200	$9,100	$18,200	$9,100	$9,100	$4,550	$9,100	$4,550	$9,100	$4,550
Line 14	*Material Cost Summary*																								
Line 15	Tube Depreciation Per Year	$40	$20	$20	$20	$20	$20	$160	$80	$240	$120	$360	$200	$80	$40	$120	$80	$200	$120	$40	$40	$80	$40	$120	$80
Line 16	Counter Depreciation Per Year	$280	$140	$140	$140	$140	$140	$560	$280	$840	$420	$1,260	$700	$280	$140	$420	$280	$700	$420	$140	$140	$280	$140	$420	$280
Line 17	Vehicle Costs Per Year	$0	$0	$0	$0	$0	$0	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600
Line 18	Misc Costs Per Year	$0	$0	$0	$0	$0	$0	$260	$130	$260	$130	$260	$130	$130	$65	$130	$65	$130	$65	$65	$32.50	$65	$32.50	$65	$32.50
Line 19	*Material Costs Per year*	$320	$160	$160	$160	$160	$160	$2,580	$2,090	$2,940	$2,270	$3,480	$2,630	$2,090	$1,845	$2,270	$2,025	$2,630	$2,205	$1,845	$1,813	$2,025	$1,813	$2,205	$1,993
Line 20	20% Contingency	$2,989	$1,495	$1,251	$641	$520	$276	$7,796	$4,058	$7,868	$4,094	$7,976	$4,166	$4,058	$2,189	$4,094	$2,225	$4,166	$2,261	$2,189	$1,273	$2,225	$1,273	$2,261	$1,309
Line 21	**Cost**	**$17,900**	**$9,000**	**$7,500**	**$3,800**	**$3,100**	**$1,700**	**$46,800**	**$24,300**	**$47,200**	**$24,600**	**$47,900**	**$25,000**	**$24,300**	**$13,100**	**$24,600**	**$13,400**	**$25,000**	**$13,600**	**$13,100**	**$7,600**	**$13,400**	**$7,600**	**$13,600**	**$7,900**

Table 7: *Cost estimates for Option 2a scenarios*

Line 1		**Option 2a: County ROW with Planned Bicycle Facilities in Suburban Hennepin County**																							
Line 2	**Comprehensiveness (miles)**	265 miles																							
Line 3	**Integrated?**	Yes						No																	
Line 4	**Density (count locations/mile)**	1.1 (#/mile)		0.5 (#/mile)		0.25 (#/miles)		1 (#/miles)						0.5 (#/miles)						0.25 (#/miles)					
Line 5	**Count Duration (days)**	1 day		1 day		1 day		1 day		4 days		7 days		1 days		4 days		7 days		1 days		4 days		7 days	
Line 6	**Count Cycle in Years**	2 years	4 years	2 years	4 years	2 years	4 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years
Line 7	Total Count Locations	318	318	132.5	132.5	53	53	265	265	265	265	265	265	132.5	132.5	132.5	132.5	132.5	132.5	66.25	66.25	66.25	66.25	66.25	66.25
Line 8	Annual Count Locations	159	80	66	33	27	13	265	133	265	133	265	133	133	66	133	66	133	66	66	33	66	33	66	33
Line 9	Locations from 1 counter in 1 season	40	40	40	40	40	40	40	40	24	24	15	15	40	40	24	24	15	15	40	40	24	24	15	15
Line 10	Additional Counters Requirec	4	2	2	1	1	1	7	4	12	6	18	9	4	2	6	3	9	5	2	1	3	2	5	3
Line 11	*Labor Cost Summary*																								
Line 12	Time required (hours)	398	199	166	83	66	33	1,237	618	1,237	618	1,237	618	618	309	618	309	618	309	309	155	309	155	309	155
Line 13	*Labor Cost Per Year*	$29,813	$14,906	$12,422	$6,211	$4,969	$2,484	$74,200	$37,100	$74,200	$37,100	$74,200	$37,100	$37,100	$18,550	$37,100	$18,550	$37,100	$18,550	$18,550	$9,275	$18,550	$9,275	$18,550	$9,275
Line 14	*Material Cost Summary*																								
Line 15	Tube Depreciation Per Year	$80	$40	$40	$20	$20	$20	$280	$160	$480	$240	$720	$360	$160	$80	$240	$120	$360	$200	$80	$40	$120	$80	$200	$120
Line 16	Counter Depreciation Per Year	$560	$280	$280	$140	$140	$140	$980	$560	$1,680	$840	$2,520	$1,260	$560	$280	$840	$420	$1,260	$700	$280	$140	$420	$280	$700	$420
Line 17	Vehicle Costs Per Year	$0	$0	$0	$0	$0	$0	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600
Line 18	Misc Costs Per Year	$0	$0	$0	$0	$0	$0	$530	$265	$530	$265	$530	$265	$265	$132.50	$265	$132.50	$265	$132.50	$132.50	$66.25	$132.50	$66.25	$132.50	$66.25
Line 19	*Material Costs Per year*	$640	$320	$320	$160	$160	$160	$3,390	$2,585	$4,290	$2,945	$5,370	$3,485	$2,585	$2,093	$2,945	$2,273	$3,485	$2,633	$2,093	$1,846	$2,273	$2,026	$2,633	$2,206
Line 20	20% Contingency	$6,091	$3,045	$2,548	$1,274	$1,026	$529	$15,518	$7,937	$15,698	$8,009	$15,914	$8,117	$7,937	$4,129	$8,009	$4,165	$8,117	$4,237	$4,129	$2,224	$4,165	$2,260	$4,237	$2,296
Line 21	**Cost**	**$36,500**	**$18,300**	**$15,300**	**$7,600**	**$6,200**	**$3,200**	**$93,100**	**$47,600**	**$94,200**	**$48,100**	**$95,500**	**$48,700**	**$47,600**	**$24,800**	**$48,100**	**$25,000**	**$48,700**	**$25,400**	**$24,800**	**$13,300**	**$25,000**	**$13,600**	**$25,400**	**$13,800**

Table 8: *Cost estimates for Option 3 scenarios*

Line 1		**Option 3: All County ROW in Minneapolis**																	
Line 2	**Comprehensiveness (miles)**	82 miles																	
Line 3	**Integrated?**	N/A																	
Line 4	**Density (count locations/mile)**	2 (#/miles)						1 (#/miles)						0.5 (#/miles)					
Line 5	**Count Duration (days)**	1 day		4 days		7 days		1 days		4 days		7 days		1 days		4 days		7 days	
Line 6	**Count Cycle in Years**	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years	1 years	2 years
Line 7	Total Count Locations	82	82	82	82	82	82	41	41	41	41	41	41	21	21	21	21	21	21
Line 8	Annual Count Locations	82	41	82	41	82	41	41	21	41	21	41	21	21	11	21	11	21	11
Line 9	Locations from 1 counter in 1 season	40	40	24	24	15	15	40	40	24	24	15	15	40	40	24	24	15	15
Line 10	Additional Counters Requirec	3	2	4	2	6	3	2	1	2	1	3	2	1	1	1	1	2	1
Line 11	*Labor Cost Summary*																		
Line 12	Time required (hours)	383	191	383	191	383	191	191	96	191	96	191	96	98	49	98	49	98	49
Line 13	*Labor Cost Per Year*	$22,960	$11,480	$22,960	$11,480	$22,960	$11,480	$11,480	$5,740	$11,480	$5,740	$11,480	$5,740	$5,880	$2,940	$5,880	$2,940	$5,880	$2,940
Line 14	*Material Cost Summary*																		
Line 15	Tube Depreciation Per Year	$120	$80	$160	$80	$240	$120	$80	$40	$80	$40	$120	$80	$40	$40	$40	$40	$80	$40
Line 16	Counter Depreciation Per Year	$420	$280	$560	$280	$840	$420	$280	$140	$280	$140	$420	$280	$140	$140	$140	$140	$280	$140
Line 17	Vehicle Costs Per Year	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600	$1,600
Line 18	Misc Costs Per Year	$164	$82	$164	$82	$164	$82	$82	$41	$82	$41	$82	$41	$42	$21	$42	$21	$42	$21
Line 19	*Material Costs Per year*	$2,304	$2,042	$2,484	$2,042	$2,844	$2,222	$2,042	$1,821	$2,042	$1,821	$2,222	$2,001	$1,822	$1,801	$1,822	$1,801	$2,002	$1,801
Line 20	20% Contingency	$5,053	$2,704	$5,089	$2,704	$5,161	$2,740	$2,704	$1,512	$2,704	$1,512	$2,740	$1,548	$1,540	$948	$1,540	$948	$1,576	$948
Line 21	**Cost**	**$30,300**	**$16,200**	**$30,500**	**$16,200**	**$31,000**	**$16,400**	**$16,200**	**$9,100**	**$16,200**	**$9,100**	**$16,400**	**$9,300**	**$9,200**	**$5,700**	**$9,200**	**$5,700**	**$9,500**	**$5,700**

next two sections explain briefly how we translated the scopes associated with each option into labor and material costs. A contingency of 20% was added to the sum of the labor and material costs (line 20).

Labor Cost Summary
(Lines 11-13)
Labor is the most significant cost component of each count program option. When considering labor costs, two parts of the count program were considered: time required to set-up and tear-down short-term count locations and time required to analyze the data collected from each location. Line 12 summarizes the estimate of hours required per year for each program option. Line 13 translates those hours to a cost based on an assumed hourly rate. Note that labor hours change significantly based on the integration decision even where the number of count locations is the same. This is based on the time required to set-up and tear-down a count location. If a count location is integrated with a vehicular count location then only the marginal time required to count that location is included as a cost. If a count location is not integrated, then all the time associated with setting-up at count location is included.

Material Cost Summary
(Lines 14-19)
Material costs are a smaller but still significant component of program costs. The material costs include the depreciation costs associated with counting equipment (counters and tubes)(lines 15 & 16), costs associated with a vehicle lease and miscellaneous equipment costs (nail, hammers, etc.) (Lines 17 & 18).

To calculate the counting equipment costs, we used the estimate of additional counters required (line 10), multiplied that by the cost of purchasing a counter and tubes and divided it by an assumed life span to produce an annual depreciation cost. The exact calculations and assumptions have been included in Appendix B. We assumed no vehicle (line 17) or miscellaneous costs (line 18) for the integrated option (line 3) because these costs are included with the costs of the vehicular counting program. Furthermore, we reduced the number of additional counters required because existing vehicular counters will be used to simultaneously count bicycles under the integrated option (see Figure 4).

II.4.2. Reference site costs

Table 9 below provides options for determining the number of reference sites in a bicycle counting program. Hennepin County is currently piloting the use of Sensys technology as reference sites for vehicle counting. As described in Section II.3.3 above, Sensys uses battery powered pucks that count traffic and send wireless signals to receivers that are installed above ground. If, as planned, Hennepin County replaces permanent vehicle counters with Sensys pucks, it would be advantageous to co-locate bicycle reference sites with vehicle reference sites.

The three options considered for the reference count locations are based on the quantity of count locations: 5, 15, or 20. Increasing the number of count locations increases the quality of the data that can be gleaned from the reference counters. For example, a network of 5 count locations should be aggregated into a single day-of-year factor (Figure 5 & 6). On the other end of the spectrum, a network of 20 count locations could be used to create day-of-year factors for each use-type (Table 1).

Table 9 also includes the option of integrating the bicycle reference count locations with the pilot reference vehicular count program mentioned above. In the absence of bicycle data on the locations, we can't say with certainty whether the proposed vehicular reference locations will serve as suitable bicycle reference locations. For this reason, we included a version 'a' and a version 'b' for each option. Version 'a' assumes three count locations can be integrated and version 'b' assumes no locations can be integrated. The cost differences are significant.

II.5. Accuracy

Accuracy is a measure of how closely the traffic volume estimate from the bicycle counting program matches the true number of bicyclists on Hennepin County roads. There are two kinds of accuracy to consider:

- **Device Accuracy**: No counting technology will provide 100% accuracy. This lack of accuracy is manageable as long as it is known and accounted for; vehicle

***Table 9**: Reference count location options*

	Option 1a	Option 1b	Option 2a	Option 2b	Option 3a	Option 3b
Integrated (Yes, No, Hybrid)	Yes	Yes	Hybrid	Hybrid	Hybrid	No
Total Coverage (# Reference Locations)	**5**	**5**	**15**	**15**	**20**	**20**
# Integrated Reference Locations	3	0	3	0	3	0
# Independant Reference Locations	2	5	12	15	17	20
Cost	**$24,296**	**$56,425**	**$137,146**	**$169,274**	**$193,570**	**$225,699**

Notes:
Options denoted with an 'a' assume partial integration with the County's pilot vehicular reference count program

counters also come with a margin of error. Information about the limitations of bicycle counting technology must be found in the literature or through testing equipment alongside manual counters or cameras. Tests of TimeMark counting devices by Hennepin County staff are currently underway.

- **Extrapolation Accuracy**: Extrapolation accuracy refers to the error that may be introduced when adjustment factors are applied to short-term counts to produce an estimate of AADB. Extrapolation accuracy depends on the duration of the short-term count and the adjustment factor used. Day-of-year factors provide the best accuracy because they account for factors such as weather or holidays that could be unique to any day of the year. Day-of-week and month-of-year factors are less accurate. However, it may be necessary to use these factors if information is desired before the end of the year.

Extrapolation accuracy should be considered in decision making because there will be a tradeoff between count duration and accuracy. As count duration increases (up to 7 days), accuracy will increase. Equipment or time restrictions may require count durations of as short as 1 day, which will have a negative impact on accuracy. Very high accuracy may not be the most important parameter to consider when making a decision. For a bicycle counting program to be useful, it needs only to provide information that is accurate enough to facilitate decision making. Hennepin County will need to decide how much accuracy is necessary for their decision making process.

Hennepin County will need to consider accuracy as only one parameter in the decision making process. It may be worthwhile to give up an extra 10% in accuracy if that means equipment can be deployed to more locations in order to increase comprehensiveness.

II.6. Other Considerations / Parameters Not Quantified

Hennepin County staff will need to consider factors that are not related to decisions about cost, comprehensiveness, or accuracy. These miscellaneous considerations may or may not be quantifiable, predictable, or scientific.

For example, Hennepin County staff have already noted that TimeMark counters must be programmed differently based on whether they are counting vehicles or bicycles. Because this process is time consuming, it is preferable if staff do not have to constantly re-program the equipment. As a result, staff may prefer to designate some counters for bikes and some for vehicles, and this decision would have significant bearing on the choice of counting strategy.

Other considerations could include a desire to utilize existing staff expertise in certain technologies, or an inability to hire additional staff or train existing staff on new technology. Staff may prefer a system that is less expensive in order to make the program more politically feasible, or a system that is less comprehensive in order to make the program less complex and more likely to be implemented.

III. RECOMMENDATIONS

This section provides recommendations for the system-wide bicycle monitoring program, which includes short-term and reference count locations. Our first recommendation is that Hennepin Count and Minneapolis collaborate to develop compatible programs. However, if Minneapolis's count program is not compatible, we have provided recommendations for Hennepin Count to count bicycles within Minneapolis.

III.1. Short-Term Count Location Recommendation

We recommend a two-phased short-term count program. Phase 1 of the recommendation is the "Pilot Program," which provides an opportunity for Hennepin County to test and refine the program. After the Pilot Program has been completed, we anticipate an incremental expansion of the count program to the "Recommended Program."

The Recommended Program has been developed per conversations with Hennepin County staff and internal analysis. Table 10 lists each of the decisions and our respective recommendations. Basically, we recommend Option 2, which is to count bicycles on suburban Hennepin County ROW with existing bicycle facilities. If the Minneapolis's bicycle count program is not Hennepin County's, we recommend that Hennepin County pursue Option 3 in addition to Option 2. Table 10 also provides recommendations for Hennepin County to conduct bicycle counts within Minneapolis (*assuming the plans are not compatible). Note that the density recommendations do not directly correspond with the densities shown on Tables 5-8. The densities in the cost tables were for illustration purposes. The densities in Table 10 are based on the segmentation process, which is described in Section IV.1.

The Pilot Program represents a targeted sampling of count locations identified for the Recommended Program (see Table 11). The only decisions that varies between the Recommended and Pilot Pograms is that of density. In this case density was based on conversations with the Hennepin County. It was determined that 60 biennial locations would be a reasonable size for the Pilot Program. The count locations were roughly split between Minneapolis and suburban Hennepin County.

The application of these recommendations is discussed in the following Implementation section. The density recommendations were based upon the segmentation process, which is discussed in the Segmentation section below.

__Table 10__: Recommended Program

	Suburban Hennepin County	Minneapolis*
Comprehensiveness	Henn. County ROW with Bicycle Facilities (130 miles)	All Hennepin County ROW (82 Miles)
Integration	Yes	N/A
Density (Count Locations/Mile)	0.5 (66 counters)	1.1 (94 counters)
Count Duration	48 hours	48 hours
Count Cycle	2 years	2 years
Cost Estimate**	± $8,000/year	± $18,000/year

III.2. Reference Count Location Recommendation

We recommend that Hennepin County begin by installing five reference count locations across the county, including within Minneapolis. Where possible, it would be useful to coordinate these locations with the pilot program currently proposed for permanent vehicular counters. Then, if Hennepin County finds it valuable, the network of reference count locations can be gradually expanded to account different use-types (utilitarian, recreation, etc.).

IV. IMPLEMENTATION

This section provides guidance on how to implement the counting program. The guidance below is specifically targeted towards the pilot recommendation.

IV.1. Segmentation

The first step in implementation is segmentation. The process of segmentation involves identifying the lengths of roadway over which AADB is consistent within a range. The process is iterative. Since no AADB information is currently available, we have identified the following criteria that might alter bike volumes along a segment:

1. Intersections with on-street bicycle facilities
2. Significant lengths of roadway (>4 miles)
3. Variations in bicycle facility-type
4. Intersections with Hennepin County ROW without bicycle facilities
5. Intersections with off-street bicycle facilities
6. Variations in vehicular AADT

The use of more criteria results in more segments and a denser network of counters. To avoid recommending an overly expensive and burdensome count program, we applied only the first three criteria for segmentation. We also used the the fourth criterion within Minneapolis. Refer to Figures 7 & 8 for the resultant network of segments. We recommend establishing one count location on each segment.

__Table 11__: Pilot Program Recommendations

	Suburban Hennepin County	Minneapolis*
Comprehensiveness	Henn. County ROW with Bicycle Facilities (130 miles)	All Hennepin County ROW (82 Miles)
Integration	Yes	N/A
Density (Count Locations/Mile)	0.2 (26 Counters)	0.4 (34 Counters)
Count Duration	48 hours	48 hours
Count Cycle	2 years	2 years
Cost Estimate**	± $3,100/year	± $7,900/Year

Once AADB becomes available, it is important to revisit and revise the original segment configuration. Generally, there are three ways by which segments could be revised:

1. If counters along a contiguous length of roadway are similar, the segments should be combined.
2. If intermediate segments exist that are not within the combination threshold, then segments should be split.
3. The ends of each segments should be verified and adjusted as necessary.

Table 12 provides thresholds for combining segments. These thresholds are based on MNDOT's thresholds for creating vehicular segments. Revisions 2 and 3 might require the targeted deployment of additional counters. These steps will be contingent upon staff and resource availability. See Figure 9 for a summary of the process.

__Table 12__: Acceptable AADB Segmentation Variation

AADT Range	Decrease	Increase
0 - 19	-100%	400%
20 - 49	-40%	50%
50 - 99	-30%	40%
100 - 299	-25%	30%
300 - 999	-20%	25%
> 1000	-15%	20%

IV.2. Identification of Count Locations

After segments have been identified,the next step is to identify the short-term and reference count locations. We recommend identifying one count location for each segment (Recommended Program). Below we describe the process of identifying these locations. We also identify count locations for a reduced program of 60 count locations per Hennepin County's request (Pilot Program). The section concludes with recommendations for selecting reference count locations using the data collected from the short-term count locations.

IV.2.1. Short-term Count Locations

If the Recommended Program is deployed in Minneapolis where the County cannot use existing vehicular count

Figure 7: Segmentation of network in Suburban Hennepin County

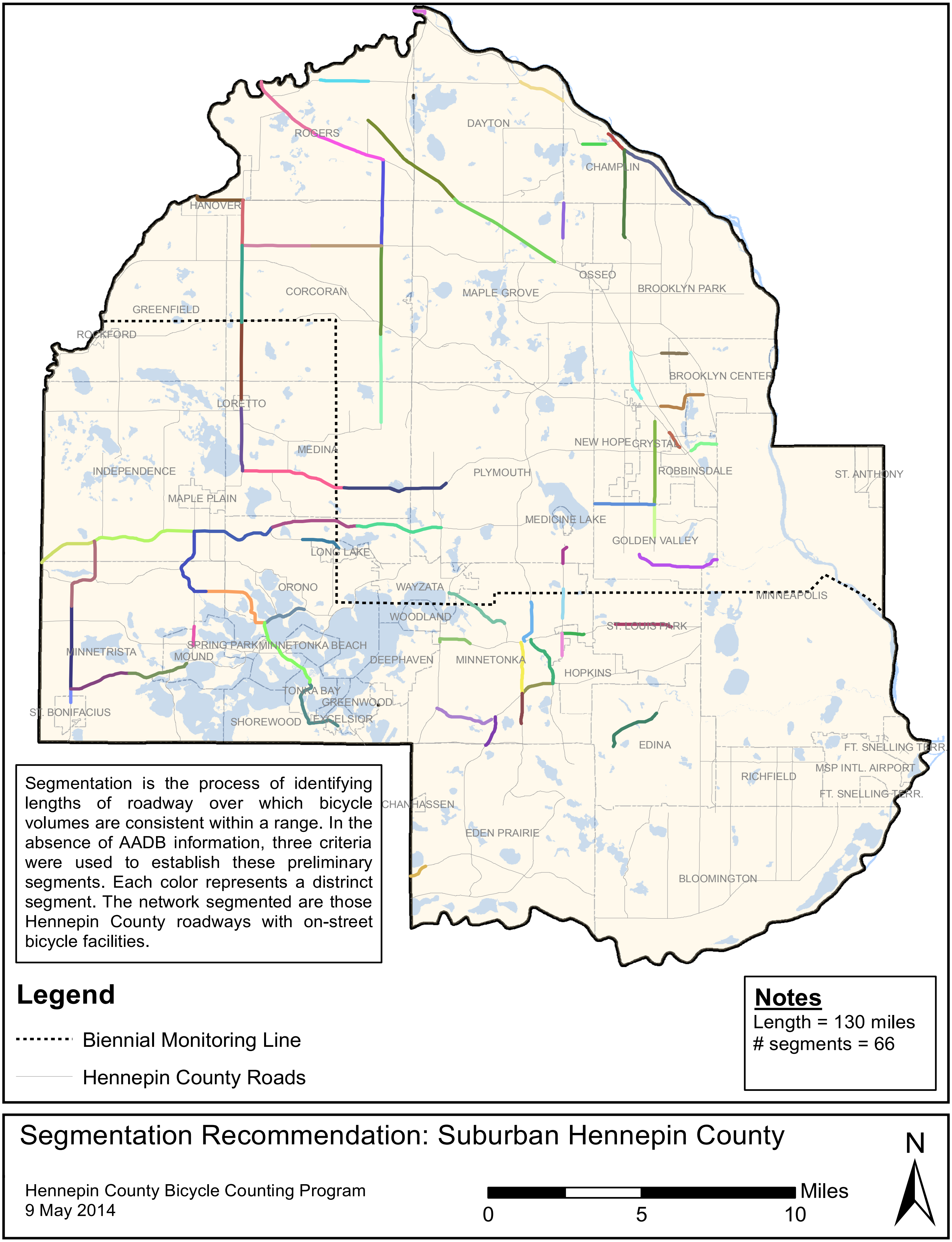


***Figure 8**: Segmentation of network in Minneapolis*

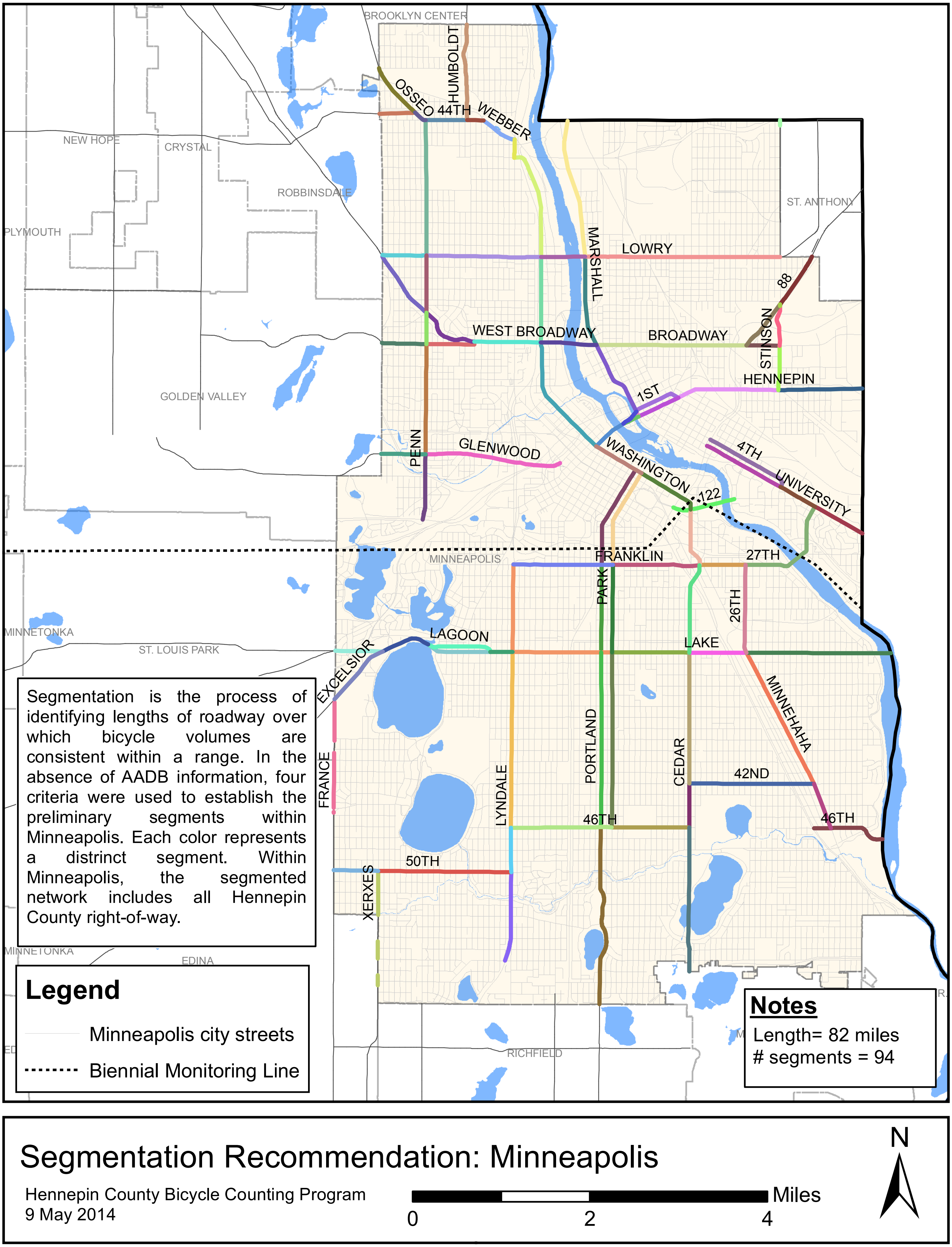


***Figure 9**: Summary of Segmentation Process*

locations, short-term counters should be located close to segment midpoints. Where possible, locate counters where they are safe to install, are secure, and are on straight segments away from intersections. Intersections and curved roadways can reduce the accuracy of the count results. In suburban Hennepin County, where we recommend integration with vehicular counters, the existing vehicular count location closest to a segment midpoint should be selected to count bicycles. Figures 10 & 11 highlight the recommended count locations. Appendix D lists the vehicular count locations that we recommend for counting bicycles in suburban Hennepin County.

Identification of the count locations for the Pilot Program requires an additional step because there are fewer count locations than there are segments. This step involves selecting a sample of count locations that are representative of the network of segments as a whole. Lacking information on AADB and use-type, we used vehicular AADT and facility-type to categorize count locations. Tables 13-16 represent the spread of existing and proposed vehicular count locations across these variables. The proposed locations match the proportion of existing locations. Additionally, because roughly half of the segments are in suburban Hennepin County and half are in Minneapolis, we split the 60 count locations between the two areas. Pilot Program locations are shown in Figures 12 & 13.

However, we cannot say with certainty whether the count locations are representative of the whole County in terms of AADB and use-type. Establishing this correlation would be dependant upon the County's knowledge of bicycle traffic patterns geographically. In the absence of this understanding, we can only say that the selected count locations represent the segments they fall within. Figure 14 illustrates the coverage of the Pilot Program.

***Table 13**: Distribution of existing vehicular counting stations by facility type and vehicular AADT, Minneapolis*

	Existing Vehicular Count Locations: MINNEAPOLIS		n=165			
Vehicular AADT	Number of Total Counting Locations			Proportion of Total		
	Bike Lane	**Bikeable Shoulder**	**No Facility**	**Bike Lane**	**Bikeable Shoulder**	**No Facility**
0-3000	0	1	4	0%	1%	2%
3001-6000	7	0	14	4%	0%	8%
6001-12000	19	0	43	12%	0%	26%
12000+	8	1	68	5%	1%	41%
Total	**34**	**2**	**129**	**100%**		
Percentage of all stations	21%	1%	78%			

***Table 14**: Distribution of proposed vehicular counting stations by facility type and vehicular AADT, Minneapolis*

	Proposed Vehicular Count Locations: MINNEAPOLIS		n=34			
Vehicular AADT	Recommended number of Counting Locations			Proportion of Total		
	Bike Lane	**Bikeable Shoulder**	**No Facility**	**Bike Lane**	**Bikeable Shoulder**	**No Facility**
0-3000	0	0	1	0%	0%	3%
3001-6000	1	0	3	3%	0%	9%
6001-12000	4	0	9	12%	0%	26%
12000+	2	0	14	6%	0%	41%
Total	**7**	**0**	**27**	**100%**		
Percentage of all stations	21%	0%	79%			

***Table 15**: Distribution of existing vehicular counting stations by facility type and vehicular AADT, HennCo*

	Existing Vehicular Count Locations: SUBURBAN		n=140	
Vehicular AADT	Number of Total Counting Locations		Proportion of Total	
	Bike Lane	Bike Shoulder	Bike Lane	Bike Shoulder
0-3000	0	8	0%	6%
3001-6000	1	45	1%	32%
6001-12000	6	66	4%	47%
12000+	0	14	0%	10%
Total	**7**	**133**	**100%**	
Percentage of all stations	5%	95%		

***Table 16**: Distribution of proposed vehicular counting stations by facility type and vehicular AADT, HennCo*

	Proposed Vehicular Count Locations: SUBURBAN		n=26	
Vehicular AADT	Recommended number of Counting Locations		Proportion of Total	
	Bike Lane	Bike Shoulder	Bike Lane	Bike Shoulder
0-3000	0	1	0%	4%
3001-6000	0	9	0%	35%
6001-12000	1	12	4%	46%
12000+	0	3	0%	12%
Total	**1**	**25**	**100%**	
Percentage of all stations	4%	96%		

Figure 10: Recommended Count Locations in Suburban Hennepin County

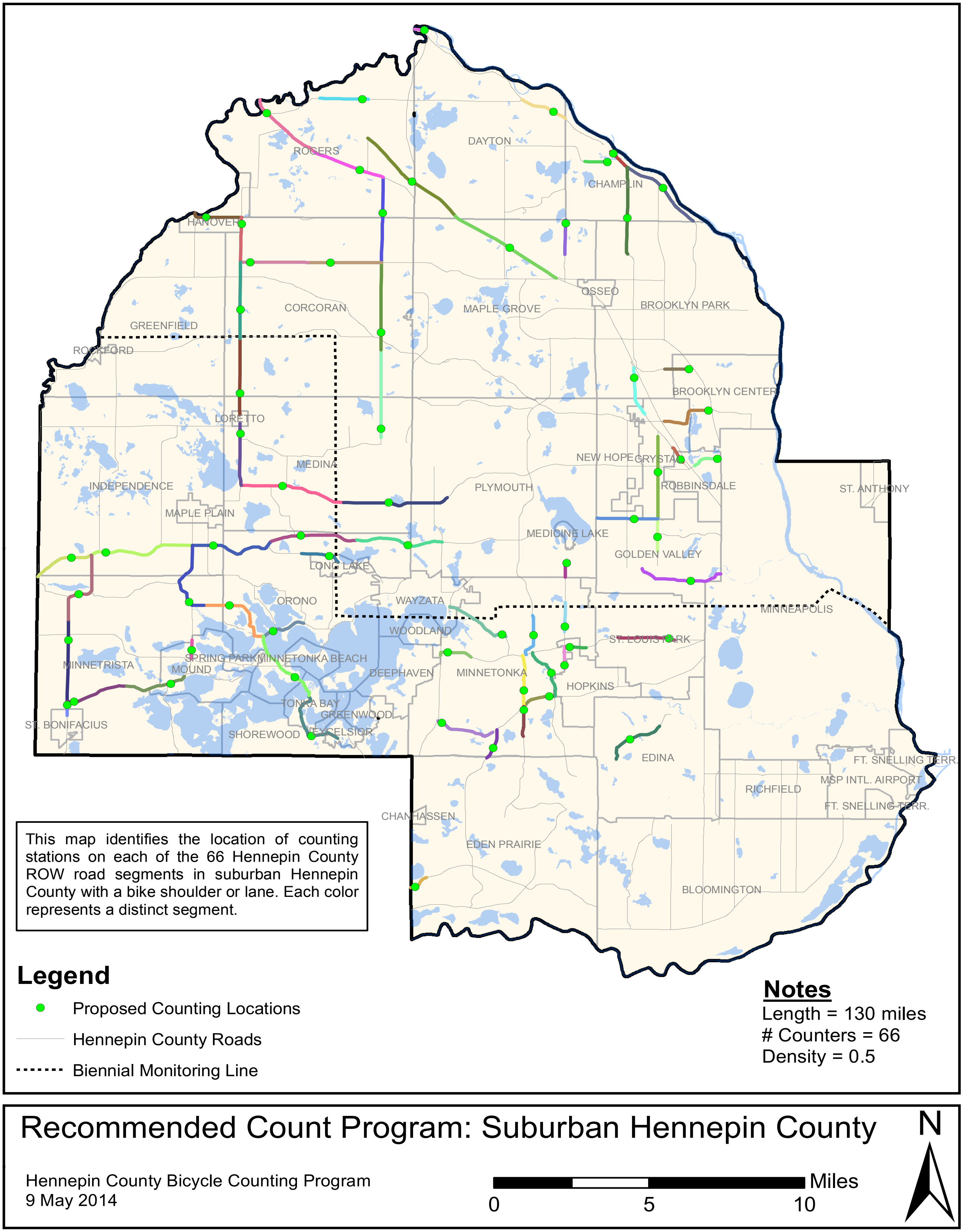


***Figure 11**: Recommended Count Locations in Minneapolis*

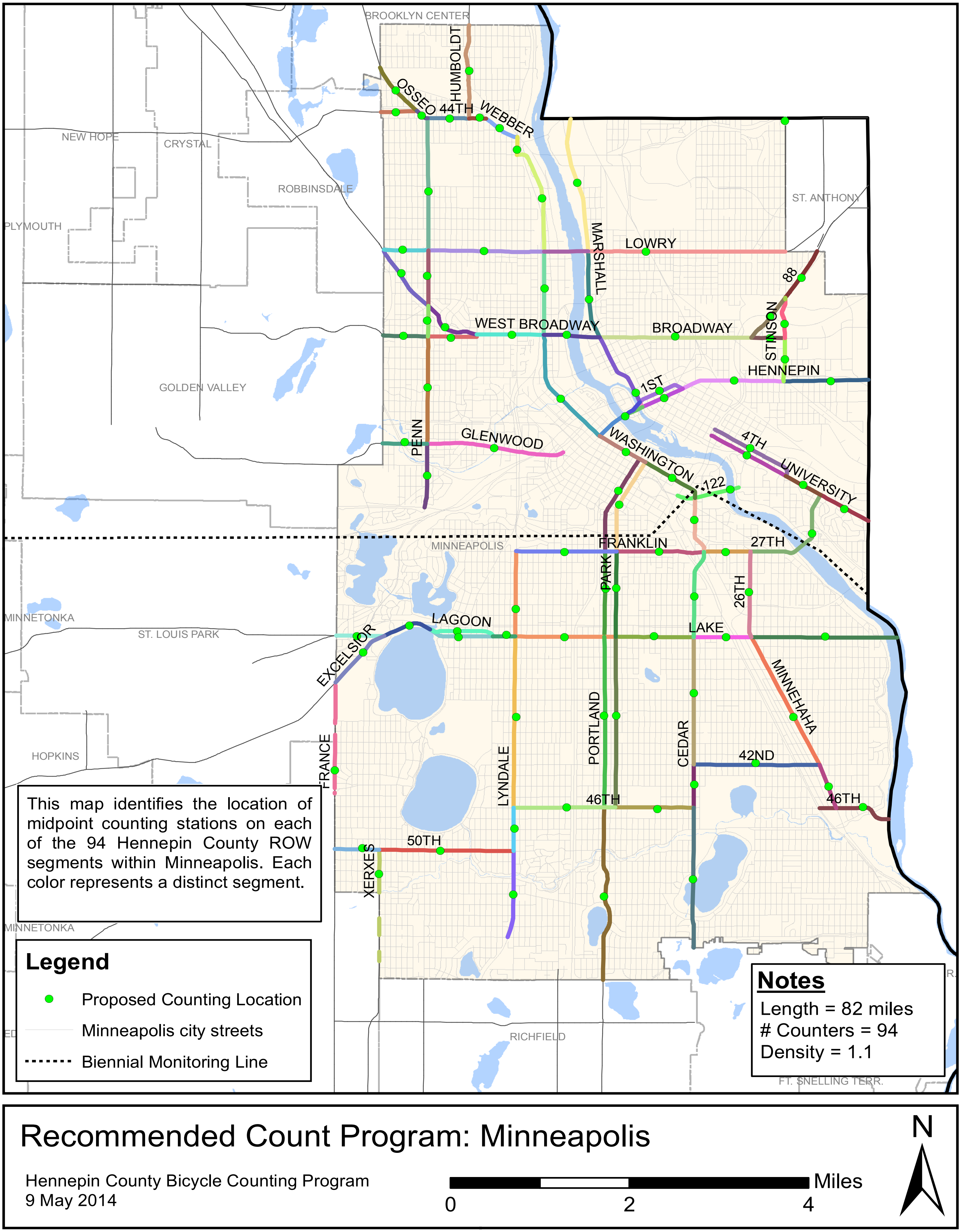


***Figure 12**: Pilot Program count locations in Suburban Hennepin County*

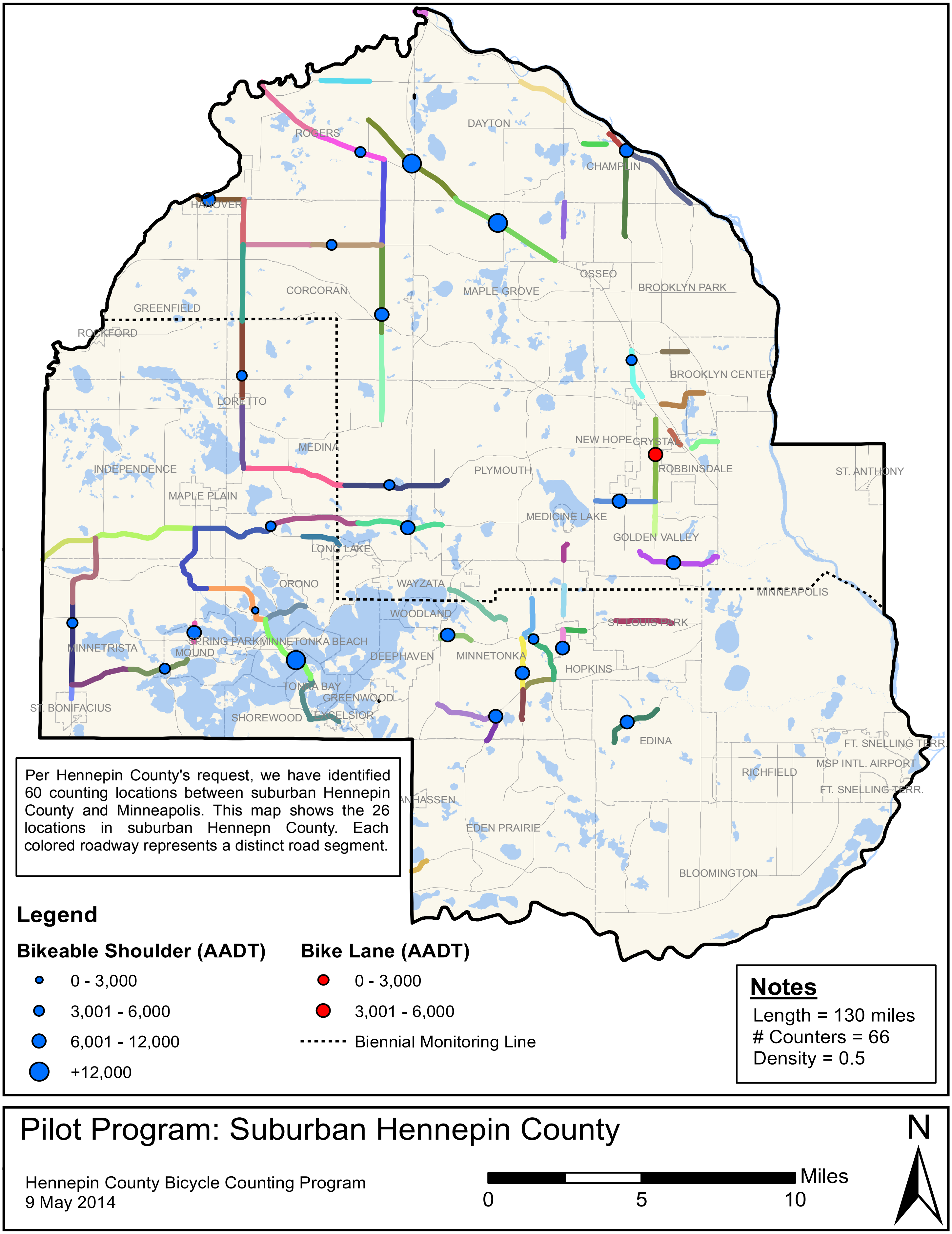


Figure 13: *Pilot Program count locations in Minneapolis*

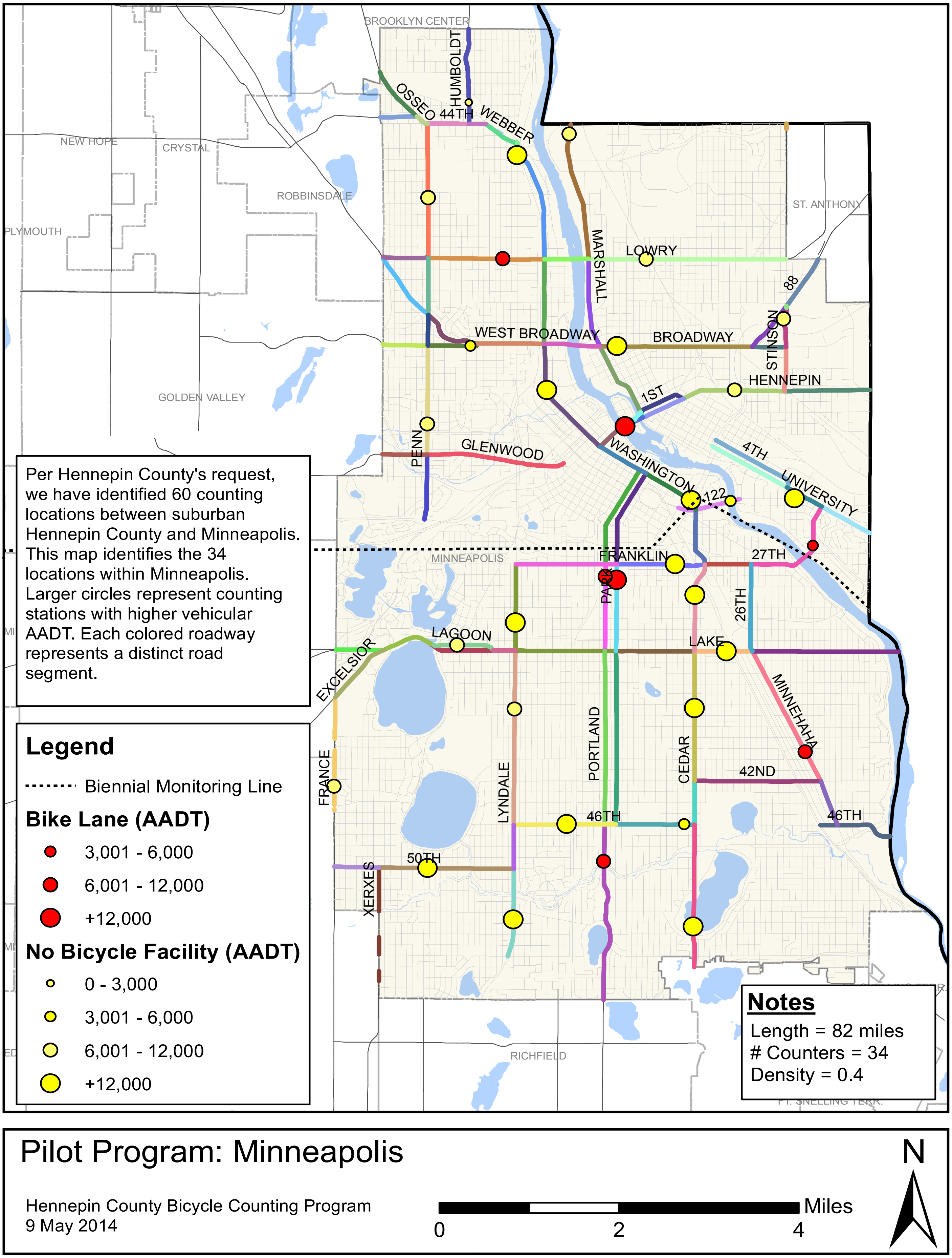
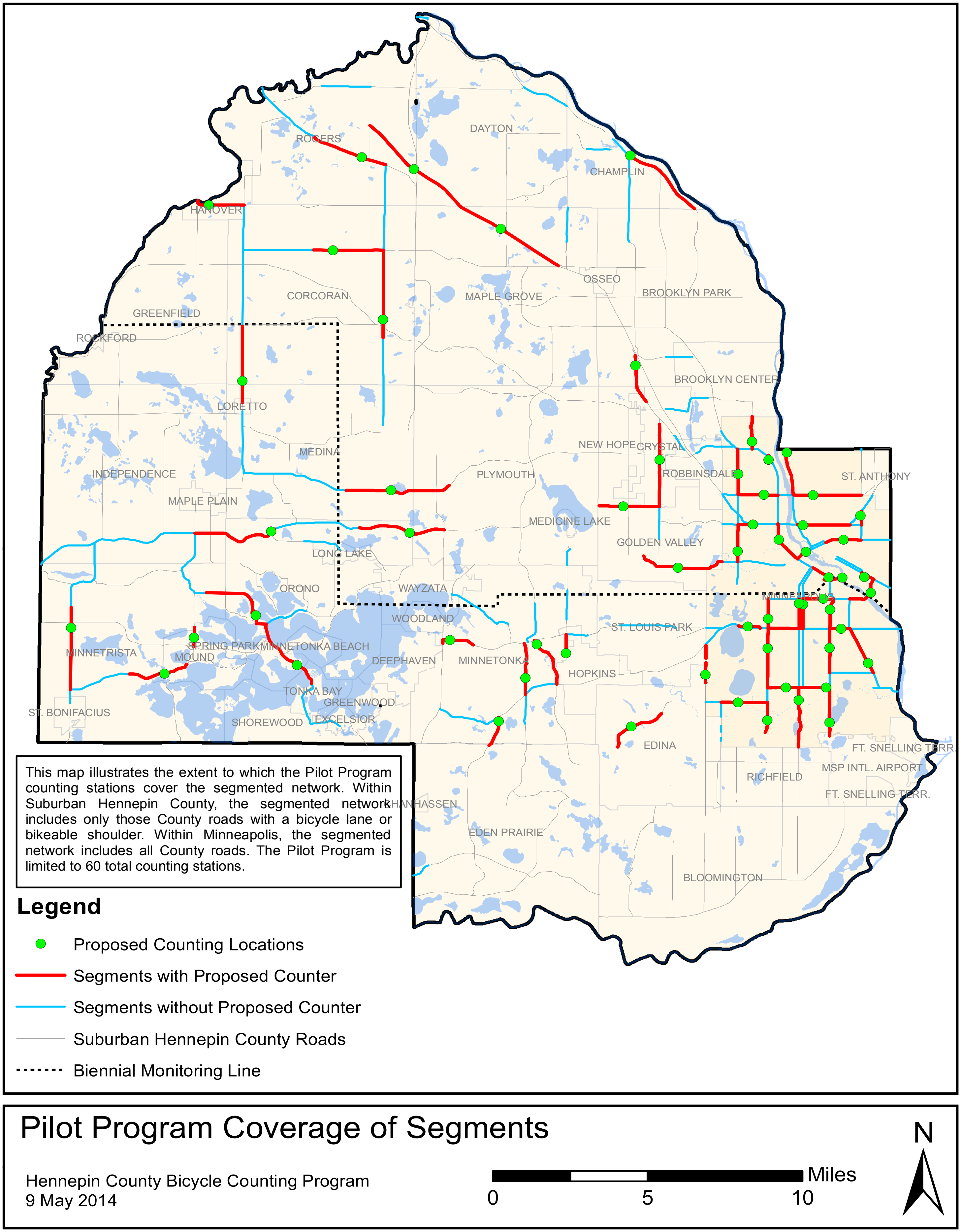


***Figure 14**: Pilot Program network coverage*



IV.2.2. Reference Count Locations

Given the expense and permanence of reference count locations, it may be best to limit the identification of these locations until data has been collected on bicycle travel behavior. The proxies identified above are not adequate for this decision. Instead, we recommend using the data collected from the short-term count locations to inform selection of reference locations.

The challenge with this process is that reference count locations are necessary to understand the data collected from short-term count locations. In the first year, no reference counters will have yet been identified. There are three options available to resolve this problem. First, Hennepin County may use data collected from an existing reference counter. This reference counter is currently maintained by MNDOT near the intersection of NE Lowry Avenue and Central Avenue NE. The benefit of this option is that it would permit the calculation of AADB rather than Average Summer Daily Bicyclists (ASDB). The drawback is that the analysis would benefit from the data of just one count location, which is less than ideal. We recommend pursuing this option if possible. This would allow the data collected in year one to be more effectively compared to subsequent years. As a second option, Hennepin County may install one a permanent reference counter on Portland Avenue South and East 37th Street. This would add to the data set already being collected by the Central and Lowry reference site.

Finally, Hennepin County might choose to install pseudo-reference counters. These are short term counters that are installed for the duration of summer and would be located in the same locations as those short term counters in the Pilot Program. Rather than producing AADB, however, they would produce ASBD, but they would permit a reasonable comparison between each of the prospective reference location sites. Figure 15 identifies the three reference location options.

Once data has been collected and analyzed, appropriate reference locations can be identified. Given our recommendation of integration with the existing vehicular count program it will not be possible to select locations by use-type. This would require a 7-day count and the vehicular count program collects 48-hour. As such we recommend using facility type as a proxy for use-type.

Figure 13 can be used to select the appropriate reference locations. If Hennepin County were to make the additional effort to determine use-type, we would recommend using Figure 14 instead. Reference locations should represent a mixture of facility-types and AADBs. Furthermore, the reference count locations should be somewhat concentrated towards Minneapolis where most cycling occurs. Finally, preference should be given to those count locations that correspond with prospective vehicular reference count locations in order to conserve resources.

***Figure 13**: Matrix for using facility type to determine reference locations*

		Facility Type			
		No Facility	Bikeable Shoulder	Bike Lane	Cycle Track
AADB	< 500				
	501-1000				
	> 1000				

***Figure 14**: Matrix for using use type to determine reference locations*

		Use Type			
		Recreational	Mixed Recreational	Mixed Utilitarian	Utilitarian
AADB	< 500				
	501-1000				
	> 1000				

IV.3. Analysis

Once data has been collected from both short-term and reference locations, the final step is analysis of the data. The analysis will produce AADB for each count location and aggregate BMT across those segments that have been measured. Step-by-step instructions for this analysis have been provided in Appendix C. This section provides a brief, qualitative summary of the process. (Note: because of the biennial nature of our recommendation, system-wide information of bicycle traffic patterns will only be available after two years of data collection.)

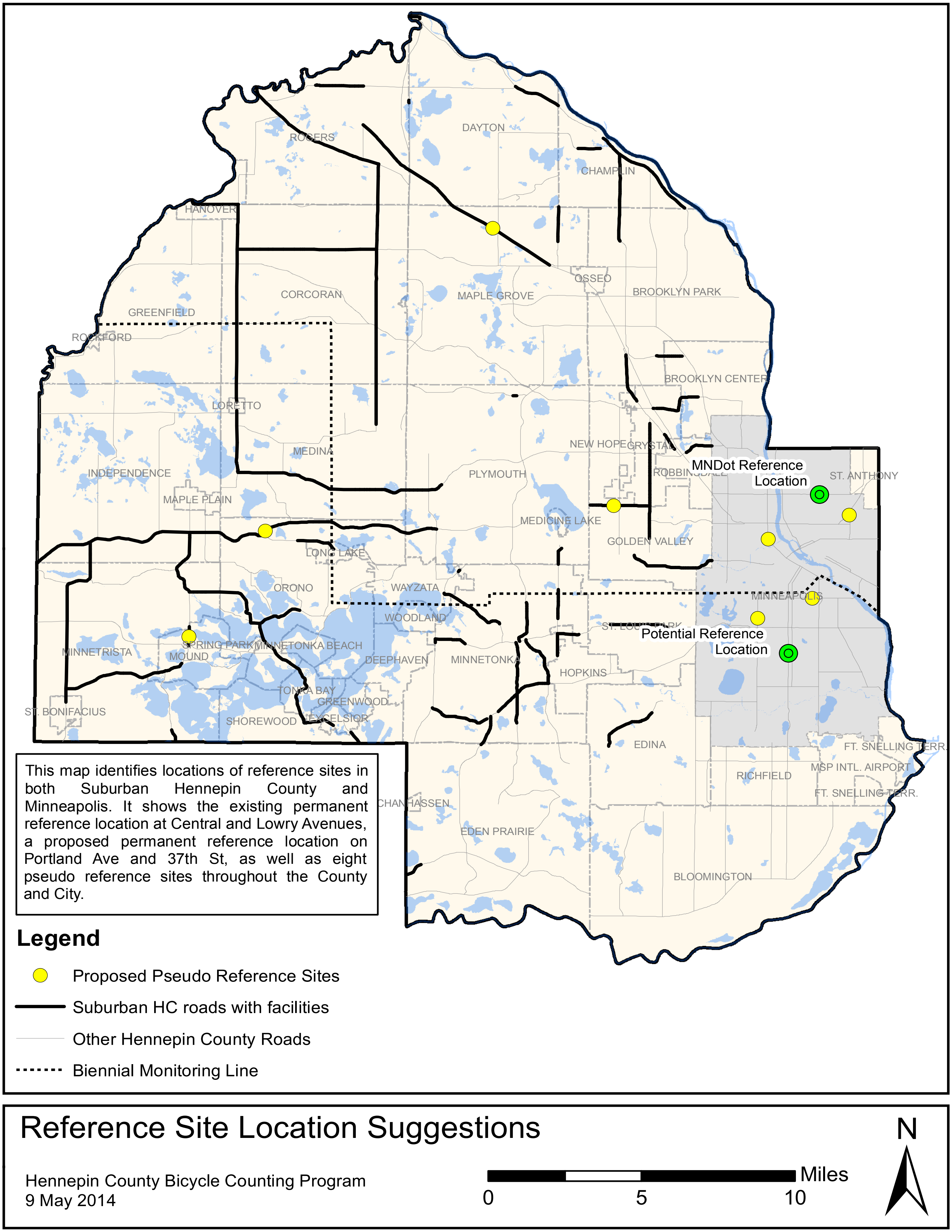
IV.3.1. AADB

At the conclusion of a year, data will have been collected from each short-term and reference count location. Calculating AADB for reference locations involves averaging the count data from each day of the year.

Calculating the AADB for the short-term locations requires additional analysis in order to normalize the influence of weather and season on bicycle traffic patterns. We recommend using the reference count locations to create day-of-year factors. A day-of-year factor is equal to the bicycle volume of a particular day divided by AADB at the same site. These factors can then be applied to the data collected at a short-term location, which is assumed to have been subject to the same weather and seasonal influences.

The above method provides guidance for estimating AADB at short duration sites at the end of a collection year. In some circumstances, AADB may be needed more immediately. There are two methods for achieving this. First, the two step method employed in vehicular analyses of applying day-of-week and month-of-year factors may be used. This step does not account for day-to-day variations in weather as well as day of year factors, but it may be adequate in the interim. An alternative method would be to calculate the day-of-year factors for year-long span other than a calendar year. For example, the day-of-year factors could be calculated from June 18th to June 17th

***Figure 15**: Three reference location options.*



of the following year. This does not produce AADB for a particular year, but it would provide an estimate of AADB nonetheless.

In the event of equipment malfunction at a short duration site, data collection may be interrupted. Please reference the discussion on missing data in the Analysis section of Appendix B for the process of producing accurate AADB estimations in the event of data gaps.

IV.3.2. BMT

Once AADB has been determined for every count location, BMT is estimated by multiplying AADB at a count location by the length of the segment it represents. This produces BMT for a segment. The BMTs for each segment can then be summed to produce a system-wide BMT. If not all segments in a system are measured, but those segments that are measured are determined to be representative of the system as a whole, the the BMT may be proportionally increased (total segment length divided by total measured segment length) to determine BMT for the system.

V. TARGETED MONITORING PROGRAM

This report so far has described a system-wide monitoring program that Hennepin County can use to determine how many bicyclists are found on roads within a chosen geographic scope. While the system-wide monitoring program is designed to estimate AABT on any given road in any given year, in special cases it will be useful to conduct short term counts at specific locations and times that do not fit in with the system-wide plan. For example, if a major change in bicycle facilities is planned on a certain road segment, Hennepin County may want to collect more timely and thorough data on that location.

Hennepin County already collects information about bicycle volumes and behavior at locations where major infrastructure changes are planned, typically using cameras. For example, staff reported that comprehensive information has been collected about Minnehaha Avenue in South Minneapolis, which is slated for major improvements in 2015.

We recommend that Hennepin County continue these efforts and consider expanding the program to collect information at more locations where infrastructure changes are planned. In addition to collecting information at sites where bicycle facility changes will be significant or politically contentious, we recommend collecting information at mill and overlay sites where changes will not be as great. These sites may also yield insight into bicycle traffic patterns. For example, simply having smoother pavement may result in an increase in bicycle volumes on a recently renovated street.

V.1. Specific Applications for Targeted Monitoring Program

V.1.1. Before-and-after infrastructure projects

Collection of before and after bicycle counts for roads slated for infrastructure changes has been identified as a priority by Hennepin County staff. This information can help staff consider the most up to date information in determining bicyclist needs in the corridor. It also provides staff with detailed information about how many bicyclists were using the corridor before and after the construction.

Table 17 on page 26 shows locations that have been identified by the authors of this report and confirmed by Hennepin County staff as priorities for short term counts in the summer of 2014. See Figure 16 for a map of these locations and Appendix B for cost estimates related to the targeted monitoring program.

Before and after counts are also relevant when trying out innovative street designs or pilot projects. Data about how the number and travel patterns of bicycles and vehicles changes due to an innovative treatment can be a crucial component of evaluating its effectiveness, especially because it allows analysis of traffic patterns and crash data.

V.1.2. Intersection signaling

Bicycle and vehicle counts at a specific intersection can be used to determine what signalization is necessary and which street has right-of-way. For example, there may be intersections where a street with heavy bicycle traffic intersects a street with light vehicle traffic. If the number of bicycles is larger than the number of cars, this may justify giving bicycles priority and facing stop signs towards the road with more cars. The City of Minneapolis used bicycle and vehicle counting data to change stop sign priorities at several intersections along the Midtown Greenway (See Appendix E for further explanation of these changes).

Some intersections may warrant a bicycle specific traffic light. Although bicycle-specific signalization is new to Hennepin County, in 2013 the FHWA issued an approval for optional use of a bicycle signal face to address certain issues at intersections (FHWA 2014). Both bicycle and vehicle counts at different approaches to an intersection of interest will be crucial in determining the most safe and efficient signalization.

V.1.3. Safe Routes to School (SRTS)

Safe Routes to School is a program that provides funding for education, outreach, and infrastructure improvements in school zones with the goal of increasing opportunities for children to walk and bike to school. SRTS related counting efforts would be unique because a specific destination like a school has a limited number of roads leading directly to that point. Automated short term counts taken at all approaches to the school (roads and bike paths) would capture every trip by bicycle or vehicle. Combined with

Figure 16: *Targeted monitoring locations across Hennepin County and Minneapolis*

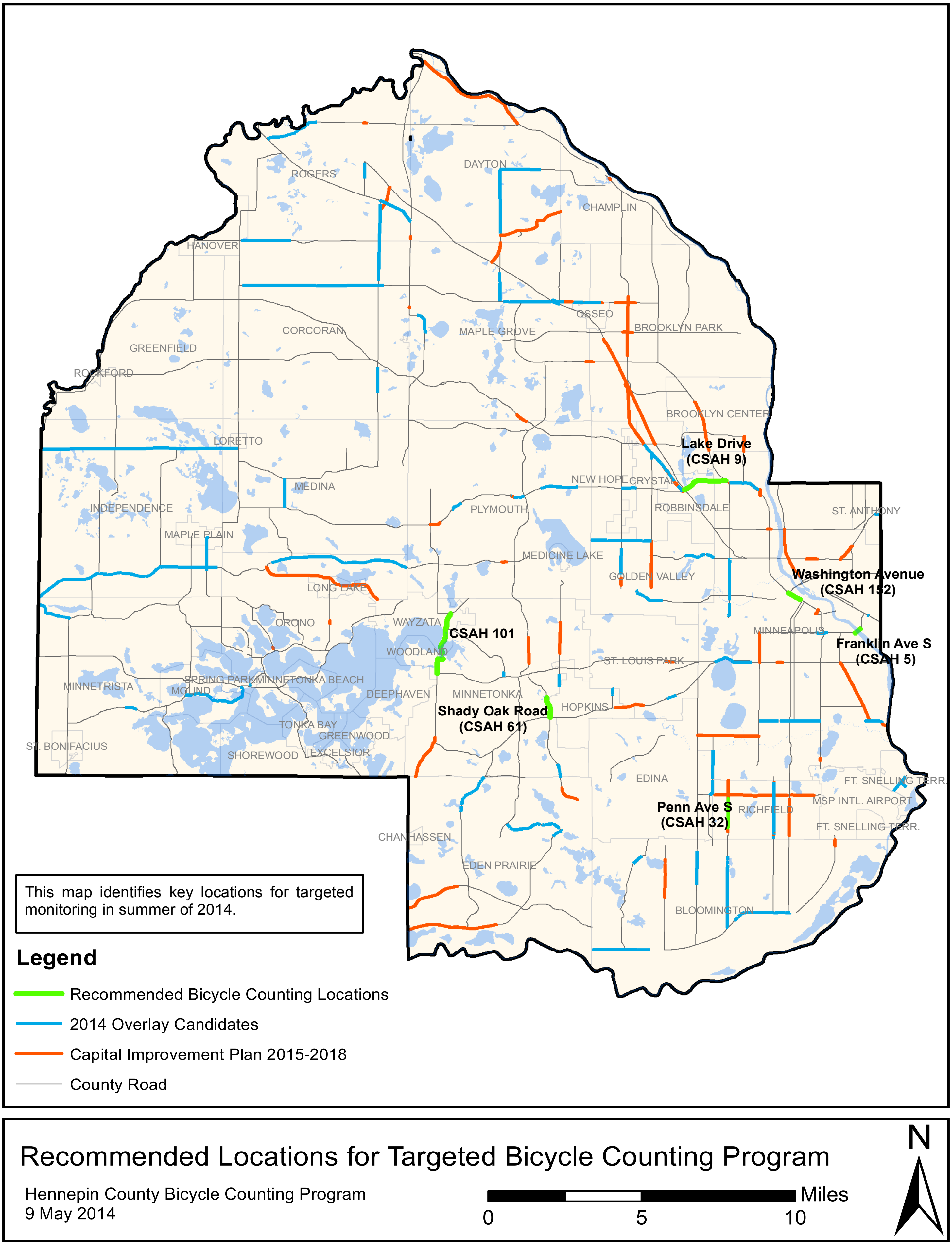


Table 17: *Recommended targeted monitoring locations for summer 2014. County staff have already begun collecting bicycle information at some of these locations*

Location	Reason
Washington Avenue (CSAH 152) from Hennepin Ave to 5th Ave S in Minneapolis	Major bicycle facility improvements are planned.
Franklin Ave Bridge (CSAH 5) in Minneapolis	Major bicycle facility improvements are planned; bridges are pinch points in general.
Lake Drive (CSAH 9) from CSHA 81 to Xerxes Avenue in Robbinsdale	Major reconstruction
County Road 101 from North of CSAH 62 to CSAH 3 in Minnetonka / Wayzata	Major reconstruction, 4 to 3 lane conversion
Shady Oak Road (County Road 61) from CSAH 3 to TH 7 in Hopkins and Minnetonka	Major reconstruction
Penn Avenue South (County Road 32) from Highway 62 to 75th Street in Richfield	Mill and overlay, 4 to 3 lane conversion

Additional opportunities if time and equipment permits:

County Road 70 east of 169, Plymouth	Mill and overlay
Minnehaha Avenue (CSAH 48) from Lake St to 46th Street, Minneapolis	Bicycle facility improvements are planned.
Elm Creek Road (County Road 202)	Partly in Elm Creek Park Reserve, which may see high bicycle traffic.

pedestrian counting data and information about the number of students attending the school, staff could determine the proportion of students using active transportation by dividing the number of students biking and walking by the total number of students.

Bicycle and vehicle counting data taken in conjunction with SRTS projects could provide valuable information on the distribution of trips between vehicles and bicycles and the proportion of students who are using active transportation. This information could help determine the effectiveness of SRTS infrastructure changes or outreach campaigns and help schools direct funding and plan infrastructure improvements in a way that is data-driven and effective. As schools also have access to health measures for their students, bicycle counting information combined with health data could provide information about the health impacts of the SRTS program.

V.1.4. Testing new counting equipment

Bicycle counting technology is changing rapidly, and Hennepin County will need to test new equipment as it becomes available. Counting equipment reserved for targeted counting projects could be used to set up counting test sites. At these sites, known equipment would be set up in parallel with new technology in order to determine data accuracy. Day of year extrapolation factors would not be needed in this situation.

V.2. Procedure for Targeted Monitoring Program sites

For the targeted monitoring program, short term bicycle counters are placed in the location where counts are needed. If information about an intersection is needed, equipment may need to be placed at several locations around the intersection.

Procedure:

- Determine location for short term counting equipment based on where information is needed and where it is technically feasible to lay equipment.
- Collect counts for 48 hours to 7 days, depending on equipment availability.
- Apply extrapolation factors to targeted counters to account for influences such as weather that are unrelated to the infrastructure project
- After the infrastructure or pilot project is completed, conduct another round of short term counts as close to the original location as possible, and calculate AADB.
- Bicycle traffic may take some time to adjust to the infrastructure changes. "After" counts will be more accurate if they are added to the list of regular (annual or bi-annual) short term counting locations in the system wide monitoring program so that changes in volume can be tracked over the course of years.

V.3. Installing permanent counters during infrastructure projects.

Infrastructure projects offer the opportunity to install permanent bicycle counters such as Sensys pucks or inductive loops beneath the pavement with minimal cost. To take advantage of this opportunity for efficiency, we recommend that Hennepin County consider installing at least one permanent bicycle counter in association with projects such as the Washington Avenue reconstruction that offer new bicycle facilities. In addition to providing long term data about bicycle volumes at this site, new bicycle facilities such as the protected bike lanes that are planned for Washington Avenue represent a new class of bicycle facility and may have unique patterns of bicycle traffic.

V.4. Real Time Bicycle Counters

The 2014 Hennepin County bicycle plan identifies increasing bicycle use as a major goal, and the County is demonstrating its commitment to encouraging the bicycle as a mode of transportation through major bicycle facility updates in upcoming road reconstruction projects such as Washington Avenue and Minnehaha Avenue, both in Minneapolis.

In conjunction with new bicycle facilities, we recommend installing at least one real-time bicycle counter. Real-time bicycle counters are installed next to a bicycle facility and digitally show how many bicycles have ridden by that day (as well as an annual total). The display is connected to an inductive loop which is embedded in the bike lane or bike path. As people bicycle by, they can see the count increase.

Credit: San Francisco Streetsblog

While not crucial to a bicycle counting program, real time counters make bicycle counting information available and interesting to the public. Bicyclists can see that the County is literally "counting" them as they ride by, which brings positive attention and publicity to the County's efforts around bicycle infrastructure. Furthermore, other road users who may not be aware how many people use the bicycle as a mode of transportation can see how many people have ridden by that day.

Digital counters have already been installed in many cities including Seattle, San Francisco, Portland, and Montreal. Seattle links their real time counters to a website that provides information on bicycle volumes at several locations that is updated daily. This procedure brings bicycle counting information into the public realm. Instead of relying on an annual report from the city or county, residents, community organizations, reporters, or anyone else can check bicycle volume data at their convenience.

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APPENDIX A

Glossary

Regional Counting Efforts

Existing Technology

GLOSSARY

AADT: Average Annual Daily Traffic, or the average number of vehicles that drive on a specific segment of a road network per day in a given year.

AADB: Average Annual Daily Bicyclists, or the average number of bicyclists that ride on a specific segment of a road network each day in a given year.

BMT: Bicycle Miles Traveled, or the total number of miles traveled by bicyclists on a network, usually reported on an annual basis.

FHWA: Federal Highway Administration

MDPW: Minneapolis Department of Public Works

MNDNR: Minnesota Department of Natural Resources

Mixed-Recreational: A bicycle facility that is used by primarily recreational traffic but that is also used by utilitarian traffic.

Mixed-Utilitarian: A bicycle facility that is used by primarily utilitarian traffic but that is also used by recreational traffic.

NBPDP: The National Bicycle and Pedestrian Documentation Project, an annual bicycle and pedestrian survey initiated by Alta Planning + Design in 2003. See http://bikepeddocumentation.org/

Off-road bicycle facility: A bicycle facility that is completely separate in space from vehicular traffic; may also be called a trail or a greenway.

On-road bicycle facility: A bicycle facility that is located within the same right of way as the roadway. Existing types of on-road bicycle facilities in Hennepin County to date include bike lanes and 5 foot shoulders.

Pseudo-reference site: During the "roll-out" phase of the bicycle counting program, a number of sites will be designated pseudo-reference sites because they will be counted using short term pneumatic tubes that will be left out for the entire summer season. These short term counting sites will serve as reference sites for the summer season. They may be turned into permanent reference sites by installing permanent equipment after roll-out if they are determined to be good locations for reference sites.

Recreational: A bicycle facility that is used by primarily recreational traffic, or bicyclists who are riding for the purpose of enjoyment or exercise.

Reference count locations: Permanent, automated count locations that collect bicycle counting information 24 hours a day, 365 days a year.

Pilot program: The first phase of the bicycle counting program, which is recommended by this report to begin in summer 2015. The Pilot Program is a small scale, preliminary plan that is feasible to implement with minimal staff time and equipment. The Pilot Program is designed to be expanded into a comprehensive counting program as time and equipment allow.

Segmentation: The process of dividing all roads of interest on a network into segments so that each segment has consistent bicycle volumes along that segment. One bicycle counter can then be used per segment.

Sensys technology: Wireless vehicle detection system used to count vehicles or cars. A small, hockey puck sized, battery operated sensor is installed in the pavement. The sensor counts traffic using magnetic sensors and sends information to an above ground receiver. See www.sensysnetworks.com

Short-term count location: Automated count locations where equipment is set up for a period of 2 to 7 days. Short term count locations provide information at many locations across a network.

Utilitarian: A bicycle facility that is used by primarily utilitarian traffic, or bicyclists that are riding for the purpose of transportation and have a specific destination. For example, utilitarian bicyclists may be bicycling to work or for errands.

REGIONAL COUNTING EFFORTS

This section contains a summary of major bicycle counting efforts that have occurred in the Minneapolis / St. Paul region to date.

American Community Survey (ACS)

The American Community Survey is the longest running source of bicycle volume information. Since 1960, the ACS has collected and reported data about how Americans get to work (Transportation Research Board, 2014, p. 2). The ACS provides the only data about bicycle volumes that is available across all cities and counties in the U.S. and so is valuable for comparisons across jurisdictions and over time. However, the ACS is self reported and, because it asks how people usually get to work, does not capture those who bike to work some of the time or those who bike for errands. Furthermore, it does not provide information about how bicycle volumes are distributed across a network.

Transit for Livable Communities (TLC)

Transit for Livable Communities is a non-profit organization that advocates for a transportation system that supports walking, biking, and transit. Since 2007, TLC has conducted an independent bike monitoring program throughout Minneapolis and St. Paul that involves annual counts at 43 benchmark locations (both on-road and off-road facilities) as well as monthly counts at six locations. Data is collected manually by volunteers for periods of two hours following protocol supplied by The National Bicycle and Pedestrian Documentation Project. In addition to numbers of bicyclists, TLC data includes information about sidewalk riding, traffic on bridges, and gender split.

According to TLC, bicycling in the Twin Cities has been increasing dramatically since 2007. Their data shows that over 8,000 bike trips were made during the 2013 annual count, a 13% increase from their 2012 count, and a 78% increase from 2007. They also found six count locations that saw an increase of bike traffic greater than 100% since 2007 (Bike Walk Twin Cities, 2013, p. 1).

Hennepin County

In the fall of 2013 Hennepin County, in partnership with the Minnesota Department of Transportation, selected 16 exploratory locations to count cyclists and pedestrians. The purpose of these counts was to test out different bicycle counting equipment for accuracy and technical feasibility. Two technologies were used to collect data at these locations: the MetroCount bike counter and the Chambers RadioBeam bike and pedestrian counter. Counters have been deployed at 14 of the 16 chosen locations, with plans to deploy counters at the additional 2 sites in the Spring of 2014. In addition, six COUNTcam video cameras were placed at six of the 14 locations for count verification (Ryan and Pieper, 2013).

Minnesota Department of Transportation (MNDOT)

The Minnesota Department of Transportation (MNDOT) initiated a pilot bike and pedestrian count program in 2012 in conjunction with the Minnesota Department of Health (MDH).

For the pilot program, MnDOT utilized the methods and protocols established by the NBPDP, and recruited volunteers to collect counts in 133 unique locations within 43 communities throughout the state. If possible, counts were recorded during evening peak hour travel times on mid-week days. According to the data collected during this pilot program the mean hourly cyclist volume was 7.5 when taking into account all times and all locations observed throughout the state. It was found that mean hourly cyclist volume was substantially higher in cities with populations greater than 100,000.

University of Minnesota-Minneapolis Department of Public Works-Minneapolis Parks and Recreation Board

Researchers and students at the Humphrey School of Public Affairs working with the Minneapolis Department of Public Works and Minneapolis Park and Recreation Board have developed a long and short term plan for counting bikes and pedestrians on off-road facilities in Minneapolis. Researchers chose six continuous count locations on multi use trails in the region and monitored these locations using Trailmaster active infrared scanners. These locations have been monitored since 2010 (Lindsey, 2013a, p. 12).

City of Minneapolis Department of Public Works

Starting in 2007, the Minneapolis Department of Public Works has been conducting annual bike and pedestrian counts in collaboration with Transit for Livable Communities (described above). Minneapolis' 2013 Bike and Pedestrian count report thoroughly analyzes the data and presents the findings visually and graphically, along with with providing detailed statistics for every count location (Minneapolis Bicycle and Pedestrian Count Report, 2013).

Minnesota Department of National Resources

The Minnesota Department of Natural Resources conducts manual counts of bicycles and pedestrians on the 10 state owned trails every 10 years. This has been conducted since 1990 (Lindsey, 2013a, p. 11).

Twin Cities Metropolitan Council

The Twin Cities Metropolitan Council oversees bicycle and pedestrian counts for 10 metropolitan park agencies. These annual count manually gather data at roughly 500 trail segments throughout the Twin Cities metro. These counts are designed to gather data on the number of visits to regional trails in the Twin Cities metro, and are not intended to gather bike volume data. Bicycle and pedestrian counts conducted for the Metropolitan Council inform the distribution of funding to the regional parks system (Lindsey, 2013, p. 11).

Three Rivers Park District

Three Rivers Park District falls under the jurisdiction of the Metropolitan Council (above) but also conducts their own independent bike and pedestrian counts. In addition to the manual counts conducted using Metropolitan Council protocols at 252 different trail locations, Three Rivers has also deployed 7 semi-permanent infrared sensors at various trail locations in their park system. They have also conducted short duration counts of two weeks to two months using automated counters at a dozen locations , and are using cameras at low-volume locations to document mode split.

EXISTING TECHNOLOGIES

This section includes a brief description of the major classes of bicycle counting technology.

Inductance Loop Detector

Inductive loops are a common permanent counting technology in which a wire coil is embedded in the pavement. The coil is electrified with an alternating current that creates an electromagnetic field above the pavement that detects any conductive object that passes through. Inductive loops are most effective when programmed to detect one type of vehicle classification and is practical for collecting either bike counts or automobile counts, but not both. Another disadvantage of inductive loops is that they must be connected to a source of electricity and require regular maintenance.

The Minnesota Department of Transportation installed a permanent inductive loop detector in a bike lane at Central Ave NE and Lowry Ave NE in Minneapolis. Other cities such as Seattle and Montreal use inductive loop technology to provide automatically updated bicycle counting information to the public on their city website (Seattle, 2014).

Infrared Sensors

Infrared technology can be split into two primary classification: Active and Passive. Active infrared sensors use a transmitter on one side of the designated count area and a reflector on the other side. When the beam transmitting to the reflector is broken, a count is logged. Passive infrared sensors detect a passing object by registering a heat differential in the detection zone. Unlike the active sensor it only needs to be mounted vertically on one side of the designated counting area (FHWA, 2013, p. 4-13).

Magnetometers

Magnetometers are small, hockey-puck sized detectors that can be installed in vehicle or bike lanes. They detect objects by sensing a change in the normal magnetic field of the area they are monitoring and wirelessly transmit a signal to an above-ground receiver. Hennepin County is in the early stages of switching to Sensys networks magnetometers for their permanent vehicle counters. In locations where Sensys equipment is used to count vehicles, it is highly cost effective to install an additional “puck” in the bike lane because the bike counter can transmit to the same receiver as the vehicle counter (Sensys Networks, 2014).

Pneumatic Tubes

Pneumatic tubes are a common portable, short term vehicle and bicycle counting device that are composed of hollow rubber tubes connected to a counting device. When vehicles or bicycles pass over the tube, they create a burst of air that is recorded by the counting device. Pneumatic tubes come in different diameters. Narrower tubes are more sensitive and therefore more conducive to detecting bicycles, which are lighter than vehicles. Pneumatic tubes can be set up so as to collect information on both vehicle and bicycle volumes simultaneously.

There are three major number of pneumatic tube technologies that are relevant to bicycle counting in this region:

- TimeMark Incorporated http://www.timemarkinc.com/
  - Used by Hennepin County for vehicle counts
  - Data is pending on sensitivity and accuracy when counting bicycles (see section X).
- Peek ADR1000 Plus http://www.peektraffic.com/adr_1000.php
  - Used by Minneapolis for vehicle counts
  - Has not yet been tested for bicycle counting capabilities.
- MetroCount http://metrocount.com/
  - Used by some jurisdictions outside Minnesota to count vehicles.
  - MetroCount vehicle counters have been proven to detect and count bicycles accurately in Boulder, Colorado (Hyde-Wright, Graham, and Nordback, 2014).

Pressure and Seismic Sensors
This technology can be used in permanent or short term counting scenarios. The sensors operate by detecting a change in weight or pressure on a particular surface area. The sensors must be placed very close to or underneath the desired area for detection, and tend to be most commonly used on trails or unpaved roads. Pressure counters have the capability of detecting direction travelled and are capable of differentiating between bikes and pedestrians. (FHWA, 2013, p. 4-17).

Video Detection
Video imaging technology counts users and recognizes mode by visual pattern recognition. Video can be analyzed either manually (in fast forward) or using software. Video detection can detect the number of bicyclists traveling in a group, a feature that most other counting technologies lack. However, video detection is costly in terms of purchasing equipment, storing data, and analyzing data.

APPENDIX B

Assumptions for Tables 4-7 (cost estimates)

Calculations for Tables 4-7 (cost estimates)

Targeted Monitoring cost estimates

This appendix summarizes the assumptions and calculations used to produce the cost estimates for each of the program options. The cost assumptions have been split in terms of integration (yes or no) and labor and materials.

Assumptions

Length of a counting season = 120 days

-This is based on a 4 month counting season from May to August.

Integration Decision "YES"

Labor Cost Assumptions

Labor Rate = $75/hour

-This hourly rate, which includes fringe costs but excludes overhead, is based on two full-time employees.

Additional time for equipment set-up = 1 hour

-This is the marginal time required for set-up and tear-down of an integrated bicycle/vehicle counting location. For example, if it currently takes 2 hours to set-up and tear-down and vehicle only count location, we assumed it would take 3 hours to configure a location to count bicycles as well.

Administration time per count location = 1.5 hours

-This is the time required to upload and analyze data from a bicycle count location.

Material Cost Assumptions

Additional counters required per count location = 1

-A vehicle count location currently requires only 1 counter. We assume a count location configured to count bicycles will require two counters. In the integrated scenario, only one additional counter will be required.

Tube Length required per site = 40 feet

-Forty feet is the assumed average road width. Eighty feet of tube will be needed but the County already has 40 feet of tube through its existing vehicular counting program.

Tube cost = $1/ft.

Lifespan of tube = 2 years

-This is an estimate of how long a tube will last on average before it needs to be replaced.

Cost per counter = $700

Lifespan of counter = 5 years

-This is an estimate of how long a counter will last on average before it needs to be replaced.

Counter depreciation = $140/year

-$Counter\ Depreciation = \frac{Cost\ per\ counter}{Lifespan\ of\ counter}$

Integration Decision "NO"

Labor Cost Assumptions

Labor rate = $60/hr

-Per conversations with Hennepin County, this labor rate estimate is based on the assumption that interns would be hired to implement an independent bicycle counting program. This estimate is the hourly rate two interns. It includes a fringe estimate but not overhead.

Time Mark relocation time = 1 day

-This is an estimate of the average time required to relocate a counter from one count location to the next.

# of set-up and tear-down location per day = 3

-Here we assume that two interns can set-up and tear-down 3 count locations in a single day on average.

Hours worked in 1 day = 8 hours

Time required for the set-up and tear-down of 1 site = 2.8 hours

-$Time\ required = \frac{Hours\ worked\ in\ 1\ day}{\#\ of\ set-up\ and\ tear-down\ locations\ per\ day}$

Administration time per count location = 2

-This is the time required to upload and analyze data from a bicycle count location. Here it is assumed that the interns are completing the analysis and that they are less efficient than existing staff (above we assume 1.5 hours per count location for existing staff).

Labor cost per site = $280

$$Labor\ cost\ per\ site = Labor\ rate * \ (Administration\ timer\ per\ count\ location + Time\ required\ for\ the\ set - up\ and\ tear - down\ of\ 1\ site)$$

Material Cost Assumptions

Additional counter required per count location = 2

- We assume a count location configured to count bicycles will require two counters.

Tube length required per site = 80 feet

-Forty feet is the assumed average road width. Thus, 80 feet of tube will be required to span the road twice.

Tube cost = $1/ft.

Lifespan of tube = 2 years

-This is an estimate of how long a tube will last on average before it needs to be replaced.

Tube depreciation per year = $40

-$Tube\ depreciation\ per\ year = \frac{Tube\ cost * Tube\ length\ required\ per\ site}{Lifespan\ of\ tube}$

Cost per counter = $700

Lifespan of counter = 5 years

-This is an estimate of how long a counter will last on average before it needs to be replaced.

Counter depreciation = $140/year

-$Counter\ Depreciation = \frac{Cost\ per\ counter}{Lifespan\ of\ counter}$

Vehicle costs per year = $1,600/year

-This is based on a $400/month vehicle rental fee and a 4 month count season.

Misc. costs per site = $2

-This includes materials like nails and equipment like hammers necessary to outfit a vehicle for an annual count program.

Calculations

Each of the calculations below summarize how each cost component in the cost spreadsheets was calculated. Variables either come from the assumptions or the decision criteria (comprehensiveness, density, count duration or count cycle in years).

$$\boldsymbol{Total\ Count\ Locations} = Comprehensiveness * density$$

$$\boldsymbol{Annual\ Count\ Locations} = \frac{Total\ Count\ Locations}{Count\ Cycle\ in\ Years}$$

$$\boldsymbol{Locations\ from\ 1\ counter\ in\ 1\ season} = \frac{Length\ of\ counting\ season}{(Count\ Duration + Time\ Mark\ relocation\ time)}$$

$$\boldsymbol{Additional\ Counters\ Required} = \frac{Annual\ Count\ Locations * Additional\ counters\ required\ per\ count\ location}{Locations\ from\ 1\ counter\ in\ 1\ season}$$

-This equation varies slightly according to the integration decision.

Labor Cost Summary

$$\boldsymbol{Time\ required} = Annual\ Count\ Locations * (Additional\ time\ for\ equipment\ setup + administration\ time\ per\ count\ location)$$

-This equation varies slightly according to the integration decision.

$$\boldsymbol{Labor\ Cost\ Per\ Year} = Time\ Required * Labor\ Rate$$

-This equation varies slightly according to the integration decision.

Material Cost Summary

$$\boldsymbol{Tube\ Depreciation\ per\ Year} = Annual\ Count\ Locations * Tube\ depreciation\ \ per\ year$$

$$\boldsymbol{Counter\ Depreciation\ per\ Year}\ =\ Annual\ Count\ Locations * Counter\ depreciation$$

$$\boldsymbol{Vehicle\ Costs\ per\ Year} = Vehicle\ costs\ per\ year$$

-Assumed no vehicle costs for the integrated option.

$$\boldsymbol{Misc.Costs\ per\ Year} = Annual\ Count\ Locations * Misc.costs\ per\ site$$

-Assumed no misc. costs for the integrated option.

Targeted Monitoring Program 2014:
Cost Estimates for recommended before-and-after counts

Labor Cost Summary	
Time required per project site	6.4 hours
Time required for entire targeted program	38.4 hours
Labor Cost Per Year	$1228.8
Material Cost Summary	
Tube Depreciation Per Year	$13
Counter Depreciation Per Year	$100
Misc Costs Per Year	$16
Material Costs Per year	$129
Total cost for "before" counts at six project sites in 2014	$1357.8

Assumptions used to calculate cost of before-and-after targeted counts in 2014:

Assumption	**Number**	**Notes**
Count Duration	7 days	For best accuracy at locations of special interest.
Total project sites	6 sites	See page 26 for locations.
Counts collected per project site	2	Assumed average of 2 because information may be needed on both sides of intersections
Counting devices needed per count	4	Individual devices are likely to be needed for each direction of traffic.
Number of counting devices dedicated to targeted program	8	4 counting devices per count, 2 counts per project location
Total pneumatic tubes per project site	16	2 tubes needed per counting device
Total time required to collect information (weeks)	6 weeks	Assuming 7 day counts, locations moved weekly.

Additional assumptions regarding before and after counts:

- Conducted using TimeMark equipment
- Separate from vehicle counts
- Vehicles used will be already leased (i.e. no additional vehicles needed for targeted program)

APPENDIX C

Instructions for analysis of short-term data

Instructions for analysis of short-term data

This section provides step-by-step instructions for calculating average annual daily bicyclists (AADB) and bicycle miles travelled (BMT) using the data collected from short-term and reference count locations.

AADB Option 1: Day-of-Year Factor (Recommended)

The following analysis establishes the preferred way of calculating AADB. The handicap of this method is that AADB cannot be calculated until the conclusion of a calendar year. If a current AADB is needed more immediately, AADB Options 2 & 3 establish reasonable alternatives.

Step 1: Obtain data from reference locations at the conclusion of a calendar year.

Reference locations provide rich data on bicycle traffic patterns at a particular location. In calculating AADB, they are particularly helpful at determining how seasons and weather impacted traffic patterns over the course of a year at a regional scale over which seasons and weather are relatively uniform.

Step 2: Calculate AADB at reference locations

As is shown in the equation below, calculating AADB for reference locations is simply a matter of summing the traffic counts that occur over the course of a particular year and dividing that value by the number of days in a year.

$$AADB_{refernce} = \frac{Total\ Annual\ Traffic}{365}$$

Unfortunately, a reference location may not produce data for each day of a year because of a malfunction or some other reason. One solution to this problem would be to modify the denominator to reflect the missing days (additional adjustments in steps 3 and 4 are necessary if this option is chosen). An alternative solution is to approximate bicycle traffic on the missing days. Literature has shown that a regression of daily bicycle volumes against weather and day-of-week variables can produce an estimate of bicycle volumes for the missing days with approximately 16% error (Wang et al., 2013).

Step 3: Calculate day-of-year factors at each reference location.

A day-of-year factor (DOYF) must be calculated for each day of the year. Day-of-year factors are only valid for the year in which they were calculated. The factor is calculated by dividing total bicycle volume over the course of an entire day by AADB at the same location.

$$DOYF_{i,\alpha} = \frac{BV_{i,\alpha}}{AADB_{i,\alpha}}$$

Where “i” is the reference location; α is the day of the year; and BV is bicycle volume for day α at location “i”. Figure 1 below provides a graphic representation of what the day-of-year factors might look like over the course of a year. The x-axis displays the day-of-year factor for every day of the year that is monitored, Jan. 1- Dec. 31. The y-axis displays the day-of-year factor or trips/AADT. The day-of-year factor shown on the y axis illustrates traffic on any particular day relative to the annual average. For example, if on April 12, the value was 1.22, this would indicate that April 12 (Tuesday) saw 122% of AADB. These values vary significantly by season and weather.

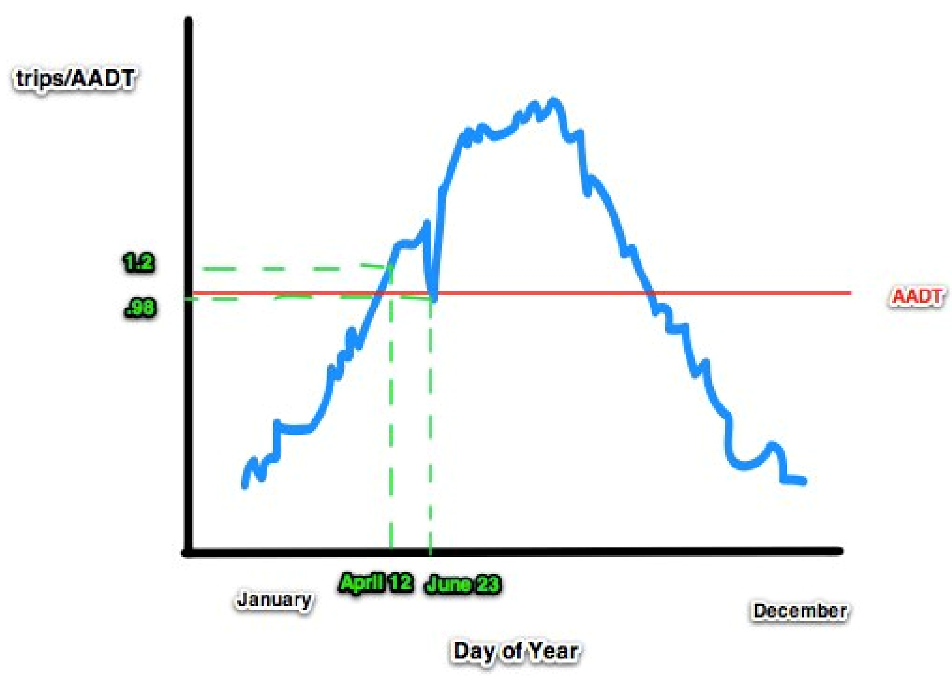


Figure 1: Example of the day-of-year factor over the course of a year.

Step 4: Aggregate day-of-year factors.
After the day-of-year factors have been calculated for each site, they must be aggregated. The method of aggregation is dependent upon which reference location program option is selected. If five reference locations are selected then the day-of-year factors for each location must be averaged to create a single day-of-year factor for each day of the year. If the County elects to pursue a more expansive program of count locations, then the day-of-year factors must be

aggregated by use-type. For example, if the County choses to install 20 reference locations (5 for each of the 4 use-type categories), then the day-of-year factors would be averaged for each use-type. It is recommended that at least 5 reference locations be aggregated to produce a suitable day-of-year factor.

$$DOYF_{Avg.,\alpha} = \frac{\sum_{i=1}^{n} DOYF_{i,\alpha}}{n}$$

Where n equals the quantity of day-of-year factors being aggregated (no less than 5); "i" is the reference location; and α is the date for which the DOYF is being calculated.

Step 5: Obtain data from short-term count locations
Data collected from short-term count locations is much less rich than data collected from reference locations. However, through the use of reference locations, much can be inferred about short-term count locations. For example, it is reasonable to assume that season and weather impact traffic patterns at reference locations in the same way that they do at short-term locations. We can thus use our knowledge of day-of-year factors at reference locations to amend the data collected at short-term locations.

Step 5: Calculate AADB at short-term count locations
The process of calculating AADB at short-term count locations is a matter of applying the appropriate day-of-year factors calculated above to each of the daily traffic totals collected at a short-term count location and averaging them.

$$AADB_{\alpha,i} = \frac{\sum_{i=A}^{Z} BV_{\alpha,i} * DOYF_{\alpha,1}}{T}$$

Where *α* is the short-term location; "i" is the day being counted; A is the first day counted; Z is the last day counted; BV represents total bicyclists on day "i"; DOYF is the day-of-year factor for day "i"; and T is the total number of days counted. In the case of a 48-hour count, which encompasses 1 full day and 2 partial days, the day-of-year factors would be applied to each of the three days, but rather that dividing the sum by 3 days, the sum would be divided by 2-days. This is logic applies to all counts durations as long as they are divisible by 24-hour increments. Once this process has been completed for each count location, AADB will be known for all measured segments.

An alternative way of synthesizing data from a 48-hour count is to use a time-of-day factor (TODF) to estimate total daily traffic for each of the partial days. This method is probably more accurate but it is also more time consuming.

$$TODF_{\alpha,i,\beta 1-\beta 2} = \sum_{REF=1}^{x} \frac{AADB_x}{BV_{x,i,\beta 1-\beta 2}}$$

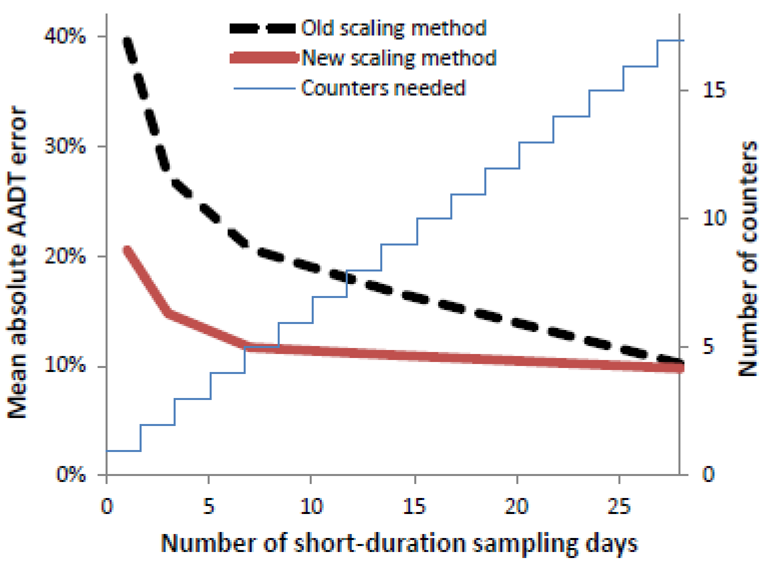
Where α is the short-term location; 'i' is the day-of-year; $\beta 1$-$\beta 2$ is the length of the count on partial day 'i'; x is the number of reference locations; and BV is the bicycle volume at reference location x on day 'i' over time $\beta 1$-$\beta 2$. This factor must then be applied to the partial day bicycle volume to create the total day estimate. Then, when calculating AADB above, T would be three instead of two for a 48-hour count.

AADB Option 2: Day-of-Year Factor Modified

Option 2 may be employed when AADB is desired for a location prior to the end of a calendar year. The steps in this process are identical to those in AADB Option 1 with one major exception. Rather than calculating day-of-year factors for a calendar year, the factors will be calculated for the most recent 365 day span.

AADB Option 3: Month-of-Year and Day-of-Week Factors

This methodology is employed for vehicular count programs. It has been employed for bicycle count programs, but the resultant error is greater than the day-of-year factor methods described above. The benefit of this approach is its relative simplicity once the month-of-year and day-of-week factors have been established. Refer to Chapter 4 of the FHWA's 2013 Traffic Monitoring Guide for details on how to calculate and apply these factors to determine AADB. The figure from Hankey et al. below provides a comparison of AADB error ("AADT" in the figure) that can be expected from employing the day-of-year factor method ("New scaling method" in the figure) versus the month-of-year and day-of-week factor method ("Old scaling method" in the figure).



BMT

Once AADT has been calculated for every segment of interest, the process of calculating BMT for each segment and the network as a whole is straightforward. The following equations assume that lengths are already established.

Step 1: Calculate BMT for each segment.
Segment BMT is calculated by multiplying a particular segment length by the AADB calculated on that segment.

$$BMT_i = AADB_i * L_i$$

Where “i” is a particular segment and L is the length of that segment.

Step 2: Calculate network BMT.
Network BMT is the sum of all segment BMTs.

$$BMT_{Total} = \sum_{i=1}^{n} BMT_i$$

Where n is the total number of segments for which BMT was calculated.

APPENDIX D

Short term counting site location information

Pseudo reference counting site location information

Short Term Sites

The list below provides details of short term monitoring locations. Average Annual Daily Traffic corresponds to the most recent vehicular counts available. In Suburban Hennepin County, this AADT data is from 2012 or 2013. Minneapolis AADT data is from 2011. In addition, please note that there is not information provided for Minneapolis locations in the Recommended Program (where a “No” exists in the Pilot_prog column). Because there are currently no existing vehicular counting stations that the bicycle counting program may integrate with, Minneapolis Recommended Program sites exist on midpoints of segments, and therefore do not have corresponding spatial and AADT data. For a map showing the location of Minneapolis Recommended Program sites, please consult Figure 10.

StationID	Sta_ID_New	Location	AADT	Hennepin_C	FacilityTy	fac_CODE	cnt_half	Pilot_prog
133	H133	E of County Line -150' E of Bridg	3375	CSAH 1	bikeable lane	A2	South	No
412	H412	N of CSAH 62	6100	-1	bikeable shoulder	B3	South	No
449	H449	E of Gleason Rd	10100	CSAH 158	bikeable shoulder	B3	South	No
771	H771	NN of TH 7	12700	CSAH 19	bikeable shoulder	B4	South	No
322	H322	650' E of CSAH 101	7600	CSAH 3	bikeable shoulder	B3	South	No
246	H246	S of CSAH 3	6550	CSAH 60	bikeable shoulder	B3	South	No
543	H543	300' S of CSAH 110	7200	CSAH 92	bikeable shoulder	B3	South	No
197	H197	400' E of CSAH 92	2950	CSAH 110	bikeable shoulder	B1	South	No
135	H135	W of CSAH 61	10400	CSAH 3	bikeable shoulder	B3	South	No
136	H136	S of TH 7	9000	CSAH 60	bikeable shoulder	B3	South	No
202	H202	200' E of CSAH 44	7400	CSAH 110, BARTLETT BLVD	bikeable shoulder	B3	South	No
580	H580	600' N of Narrows Bridge	12200	CSAH 19	bikeable shoulder	B4	South	No
345	H345	800' N of TH 7	3075	CSAH 61	bikeable shoulder	B2	South	No
344	H344	N of TH 7	10700	CSAH 73, HOPKINS CROSS RD	bikeable shoulder	B3	South	No
158	H158	E of CSAH 101	11300	CSAH 5	bikeable shoulder	B3	South	No
195	H195	N. of CSAH 15	10400	CSAH 110, COMMERCE BLVD	bikeable shoulder	B3	South	No
369	H369	E of CSAH 73	8550	CSAH 5, MINNETONKA BLVD	bikeable shoulder	B3	South	No
106	H106	200' S of CSAH 15	4350	CSAH 92	bikeable shoulder	B2	South	No
299	H299	100' West of Yosimite	13700	CSAH 5	bikeable shoulder	B4	South	No
395	H395	NN of CSAH 5	9400	CSAH 61	bikeable shoulder	B3	South	No

StationID	Sta_ID_New	Location	AADT	Hennepin_C	FacilityTy	fac_CODE	cnt_half	Pilot_prog
600	H600	N of Boundry Creek Rd	3375	CR 202	bikeable shoulder	B2	North	No
396	H396	E of CSAH 123	9150	-1	bikeable shoulder	B3	North	No
804	H804	N of 109th Ave	6950	CR 103	bikeable shoulder	B3	North	No
78	H78	N of CR 117	5900	CR 116	bikeable shoulder	B2	North	No
702	H702	E of CSAH 14	5250	CSAH 12	bikeable shoulder	B2	North	No
707	H707	W of CSAH 13	12800	CSAH 81	bikeable shoulder	B4	North	No
84	H84	W of CSAH 150	4650	CSAH 116	bikeable shoulder	B2	North	No
640	H640	W OF CHAMPLIN DR	7500	CSAH 121, HAYDEN LAKE RD	bikeable shoulder	B3	North	No
700	H700	E of TH 169	7600	CSAH 12	bikeable shoulder	B3	North	No
83	H83	N of CSAH 144	6350	CSAH 116	bikeable shoulder	B3	North	No
92	H92	NN of CSAH 121	5950	CSAH 12	bikeable shoulder	B2	North	No
534	H534	W of CSAH 101	7850	CSAH 144	bikeable shoulder	B3	North	No
455	H455	E of County Line-E of Br.	4800	CSAH 12	bikeable shoulder	B2	North	No
65	H65	S of CSAH 9	7150	CSAH 102	bikeable lane	A3	North	Yes
195	H195	N. of CSAH 15	10400	CSAH 110, COMMERCE BLVD	bikeable shoulder	B3	South	Yes
801	H801	E of Hunter DR	6900	CSAH 6	bikeable shoulder	B3	North	Yes
710	H710	W of CSAH 121	27400	CSAH 81	bikeable shoulder	B4	North	Yes
449	H449	E of Gleason Rd	10100	CSAH 158	bikeable shoulder	B3	South	Yes
583	H583	400' S of CSAH 3	6700	CSAH 4	bikeable shoulder	B3	South	Yes
136	H136	S of TH 7	9000	CSAH 60	bikeable shoulder	B3	South	Yes
249	H249	150' W of CSAH 44	5650	CSAH 110, BARTLETT BLVD	bikeable shoulder	B2	South	Yes
580	H580	600' N of Narrows Bridge	12200	CSAH 19	bikeable shoulder	B4	South	Yes
344	H344	N of TH 7	10700	CSAH 73, HOPKINS CROSS RD	bikeable shoulder	B3	South	Yes
147	H147	200' S of CSAH 5	4050	CSAH 61	bikeable shoulder	B2	South	Yes
158	H158	E of CSAH 101	11300	CSAH 5	bikeable shoulder	B3	South	Yes
106	H106	200' S of CSAH 15	4350	CSAH 92	bikeable shoulder	B2	South	Yes
232	H232	100' N of CSAH 19	1675	CSAH 151	bikeable shoulder	B1	South	Yes
851	H851	W OF TH 100	8500	CSAH 40	bikeable shoulder	B3	North	Yes
121	H121	300' E of TH 12	4700	CSAH 6	bikeable shoulder	B2	South	Yes
289	H289	W of CSAH 156	11000	-1	bikeable shoulder	B3	North	Yes
545	H545	E of Hunter Drive	4475	CSAH 24	bikeable shoulder	B2	North	Yes

StationID	Sta_ID_New	Location	AADT	Hennepin_C	FacilityTy	fac_CODE	cnt_half	Pilot_prog
600	H600	N of Boundry Creek Rd	3375	CR 202	bikeable shoulder	B2	North	No
396	H396	E of CSAH 123	9150	-1	bikeable shoulder	B3	North	No
804	H804	N of 109th Ave	6950	CR 103	bikeable shoulder	B3	North	No
78	H78	N of CR 117	5900	CR 116	bikeable shoulder	B2	North	No
702	H702	E of CSAH 14	5250	CSAH 12	bikeable shoulder	B2	North	No
707	H707	W of CSAH 13	12800	CSAH 81	bikeable shoulder	B4	North	No
84	H84	W of CSAH 150	4650	CSAH 116	bikeable shoulder	B2	North	No
640	H640	W OF CHAMPLIN DR	7500	CSAH 121, HAYDEN LAKE RD	bikeable shoulder	B3	North	No
700	H700	E of TH 169	7600	CSAH 12	bikeable shoulder	B3	North	No
83	H83	N of CSAH 144	6350	CSAH 116	bikeable shoulder	B3	North	No
92	H92	NN of CSAH 121	5950	CSAH 12	bikeable shoulder	B2	North	No
534	H534	W of CSAH 101	7850	CSAH 144	bikeable shoulder	B3	North	No
455	H455	E of County Line-E of Br.	4800	CSAH 12	bikeable shoulder	B2	North	No
65	H65	S of CSAH 9	7150	CSAH 102	bikeable lane	A3	North	Yes
195	H195	N. of CSAH 15	10400	CSAH 110, COMMERCE BLVD	bikeable shoulder	B3	South	Yes
801	H801	E of Hunter DR	6900	CSAH 6	bikeable shoulder	B3	North	Yes
710	H710	W of CSAH 121	27400	CSAH 81	bikeable shoulder	B4	North	Yes
449	H449	E of Gleason Rd	10100	CSAH 158	bikeable shoulder	B3	South	Yes
583	H583	400' S of CSAH 3	6700	CSAH 4	bikeable shoulder	B3	South	Yes
136	H136	S of TH 7	9000	CSAH 60	bikeable shoulder	B3	South	Yes
249	H249	150' W of CSAH 44	5650	CSAH 110, BARTLETT BLVD	bikeable shoulder	B2	South	Yes
580	H580	600' N of Narrows Bridge	12200	CSAH 19	bikeable shoulder	B4	South	Yes
344	H344	N of TH 7	10700	CSAH 73, HOPKINS CROSS RD	bikeable shoulder	B3	South	Yes
147	H147	200' S of CSAH 5	4050	CSAH 61	bikeable shoulder	B2	South	Yes
158	H158	E of CSAH 101	11300	CSAH 5	bikeable shoulder	B3	South	Yes
106	H106	200' S of CSAH 15	4350	CSAH 92	bikeable shoulder	B2	South	Yes
232	H232	100' N of CSAH 19	1675	CSAH 151	bikeable shoulder	B1	South	Yes
851	H851	W OF TH 100	8500	CSAH 40	bikeable shoulder	B3	North	Yes
121	H121	300' E of TH 12	4700	CSAH 6	bikeable shoulder	B2	South	Yes
289	H289	W of CSAH 156	11000	-1	bikeable shoulder	B3	North	Yes
545	H545	E of Hunter Drive	4475	CSAH 24	bikeable shoulder	B2	North	Yes

StationID	Sta_ID_New	Location	AADT	Hennepin_C	FacilityTy	fac_CODE	cnt_half	Pilot_prog
324	H324	800' N of TH 55	5600	CSAH 19	bikeable shoulder	B2	South	Yes
431	H431	S of I-94	5800	CSAH 8	bikeable shoulder	B2	North	Yes
225	H225	N of CSAH 10	6600	CR 116	bikeable shoulder	B3	North	Yes
648	H648	E. E. of CSAH 19	5800	-1	bikeable shoulder	B2	North	Yes
396	H396	E of CSAH 123	9150	-1	bikeable shoulder	B3	North	Yes
707	H707	W of CSAH 13	12800	CSAH 81	bikeable shoulder	B4	North	Yes
84	H84	W of CSAH 150	4650	CSAH 116	bikeable shoulder	B2	North	Yes
701	H701	E of CR 103	8700	CSAH 12	bikeable shoulder	B3	North	Yes
M302	M302	153 E BRYANT	8500	CSAH 153, LOWRY AV	Bike Lane	A3	North	Yes
M147	M147	35 S 49TH	12000	CSAH 35, PORTLAND AV	Bike Lane	A3	South	Yes
M122	M122	48 S 38TH	10100	CSAH 48, MINNEHAHA AV	Bike Lane	A3	South	Yes
M70	M70	33 S 5	14400	CSAH 33, PARK AV S	Bike Lane	A4	South	Yes
M69	M69	35 S 5	7800	CSAH 35, PORTLAND AV S	Bike Lane	A3	South	Yes
M43	M43	52 W 23	26500	CSAH 52, HENNEPIN AV	Bike Lane	A4	North	Yes
M300	M300	5 S 94	3900	CSAH 5, 27TH AV SE	Bike Lane	A2	North	Yes
M36	M36	66 W 47	12300	CSAH 66, BROADWAY AV	No Facility	B4	North	Yes
M179	M179	2 N 55	9200	CSAH 2, PENN AV	No Facility	B3	North	Yes
M220	M220	52 W 35W	11500	CSAH 52, HENNEPIN AV	No Facility	B3	North	Yes
M614	M614	152 S 42ND AVE N	12400	CSAH 152, LYNDALE AV	No Facility	B4	North	Yes
M210	M210	2 N 37TH	7900	-1	No Facility	B3	North	Yes
M217	M217	66 E IRVING	4300	CSAH 66, GOLDEN VALLEY RD	No Facility	B2	North	Yes
M404	M404	122 RIVER BR	5900	-1	No Facility	B2	North	Yes
M2	M2	57 N 47TH	2900	CSAH 57, HOMBOLDT AV	No Facility	B1	North	Yes
M219	M219	27 S 88	10900	CSAH 27, STINSON BLVD	No Facility	B3	North	Yes
M17	M17	23 S 37TH	7500	CSAH 23, EAST RIVER RD	No Facility	B3	North	Yes
M24	M24	153 E 47	9100	CSAH 153, LOWRY AV	No Facility	B3	North	Yes
M407	M407	122 E OAK	14800	CSAH 122, WASHINGTON AV SE	No Facility	B4	North	Yes
M367	M367	152 E 35W	17300	CSAH 152, WASHINGTON AV S	No Facility	B4	North	Yes
M361	M361	152 S PLY AV	12600	CSAH 152, WASHINGTON AV S	No Facility	B4	North	Yes
M325	M325	22 S 54TH ST	13000	CSAH 22, LYNDALE AV	No Facility	B4	South	Yes

StationID	Sta_ID_New	Location	AADT	Hennepin_C	FacilityTy	fac_CODE	cnt_half	Pilot_prog
M374	M374	152 N 26TH	13600	CSAH 152, CEDAR AV	No Facility	B4	South	Yes
M397	M397	46 W 35W	16700	CSAH 46, 46TH ST	No Facility	B4	South	Yes
M393	M393	22 N 36TH	12000	CSAH 22, LYNDALE AV	No Facility	B3	South	Yes
M400	M400	46 W 152	4000	CSAH 46, 46TH ST	No Facility	B2	South	Yes
M349	M349	17 S 42ND ST	10700	CSAH 17, FRANCE AV	No Facility	B3	South	Yes
M386	M386	43 W HENN	11000	CSAH 43, LAGOON AV	No Facility	B3	South	Yes
M381	M381	152 N LK NOKNMIS PKWY	17500	CSAH 152, CEDAR AV S	No Facility	B4	South	Yes
M391	M391	3 W 55	15800	CSAH 3, LAKE ST	No Facility	B4	South	Yes
M226	M226	5 W 55	13900	CSAH 5, FRANKLIN AV E	No Facility	B4	South	Yes
M330	M330	22 S 27TH ST	19800	CSAH 22, LYNDALE AV	No Facility	B4	South	Yes
M377	M377	152 N 36TH	14200	-1	No Facility	B4	South	Yes
M328	M328	21 E PENN	12300	CSAH 21, 50TH ST	No Facility	B4	South	Yes

Pseudo Reference Sites

The list below gives details of the pseudo reference locations. These locations correspond to Figure 16.

StationID	Sta_ID_New	Location	AADT	Hennepin_C	FacilityTy	fac_CODE	cnt_half	Prog
710	H710	W of CSAH 121	27400	CSAH 81	bikeable shoulder	B4	North	Pseudo_Ref
M219	M219	27 S 88	13000	CSAH 27, STINSON BLVD	No Facility	B3	North	Pseudo_Ref
M361	M361	152 S PLY AV	12600	CSAH 152, WASHINGTON AV S	No Facility	B4	North	Pseudo_Ref
M226	M226	5 W 55	17100	CSAH 5, FRANKLIN AV E	No Facility	B4	South	Pseudo_Ref
M330	M330	22 S 27TH ST	19800	CSAH 22, LYNDALE AV	No Facility	B4	South	Pseudo_Ref
195	H195	N. of CSAH 15	10400	CSAH 110, COMMERCE BLVD	bikeable shoulder	B3	South	Pseudo_Ref
121	H121	300' E of TH 12	4700	CSAH 6	bikeable shoulder	B2	South	Pseudo_Ref
289	H289	W of CSAH 156	11000	-1	bikeable shoulder	B3	North	Pseudo_Ref

APPENDIX E

Midtown Greenway Traffic Signalization Memo

Pneumatic Tube Accuracy Memo

City Hall, Room 233
350 South 5th Street
Minneapolis, MN 55415
Phone: 673-2411
Fax: 673-2149

Public Works Department
Traffic and Parking Services

Memo

To:	Steve Mosing, Traffic and Parking Services Shaun Murphy, NTP Project Coordinator	From:	Mike Anderson, PE, PTOE
Re:	**Midtown Greenway At-Grade Crossings**	Date:	February 15, 2010
CC:		Pages:	3

The City of Minneapolis will be implementing new at-grade trail crossings for the Midtown Greenway, a shared-use bicycle path, at the following public roadway crossings:

- Humboldt Avenue S
- Irving Avenue S
- James Avenue S
- 5th Avenue S
- E 28th Street

Layout recommendations for these mid-block crossings are based on adherence to the City of Minneapolis's ***Guidelines for the Installation of Traffic Control Devices at Intersections of At-Grade Shared-Use Path and Public Streets***, dated July 16th, 2009, and through correspondence with City Staff. Within these guidelines, there are steps to determine the appropriate layout for each type of mid-block crossing. An overview of the steps is provided below:

1) Determine the roadway function classification. This is used to maintain the roadway network hierarchy and balance mobility and safety at crossings.

2) Use Table 2, Street Type/Function Classification and Traffic Control Hierarchy at Public Street/Shared-use Path Crossing, from the City's guidelines to determine the traffic control options for assignment of priority at shared-use path crossings.

3) If a Stop/Yield sign facing the path or street is recommended, priority must be assigned between the shared-use path and public roadway crossing. The shared-use path could be given priority of the following two conditions are met:

   - The shared-use path daily through volume (total of all users) is greater than the intersecting roadway ADT; and

- A site investigation does not find any characteristics that would cause a safety hazard by stopping or yielding the roadway.

4) Recommend an example layout from the City's guidelines or an alternative layout.

Table 1-1 details the steps taken and the data used to arrive at the recommended layouts for each crossing. Below Table 1-1 a more depth description of each crossing is provided.

Table 1-1. Crossing Recommendation Matrix for a Public Street/Shared-Use Path

Crossing	Type of X-ing	Street Class	Traffic Control Options[1.]	Street ADT[2.]	Grnwy EDT[3.]	Figure	Rec. Control	Other Recs.
James Avenue S	Mid-block Crossing	Local Street	Stop/Yield Sign Facing Path --or-- Stop/Yield Sign Facing Street	420	3,280	Example 3, Scenario 2	Stop Signs Facing the Street	1. Remove Stop Signs facing Trail 2. Move Ex NB Stop Sign further North
Irving Avenue S	Mid-block Crossing	Local Street	Stop/Yield Sign Facing Path --or-- Stop/Yield Sign Facing Street	2,026	3,280	Example 3, Scenario 2	Stop Signs Facing the Street	1.Remove Stop Signs facing Trail 2. Install Overhead Lighting 3. Move NB Stop Sign Further North
Humboldt Avenue S	Mid-block Crossing	Local Street	Stop/Yield Sign Facing Path --or-- Stop/Yield Sign Facing Street	2,400	3,280	Example 3, Scenario 2	Stop Signs Facing the Street	1. Remove Stop Signs facing Trail 2. Install Overhead Lighting
5th Avenue S	Mid-block Crossing	Local Street	Stop/Yield Sign Facing Path --or-- Stop/Yield Sign Facing Street	1,680	2,900	Example 3, Scenario 2	Yield Signs Facing the Street	1. Remove Stop Signs Facing Trail
E 28th Street	Mid-block Crossing	B Minor Arterial	Stop Sign Facing Path --or-- Traffic Signal	7,267	2,740	28th St. Layout[4.]	Overhead Flasher	1. Reduce Road from 4-Lanes to 2-Lanes at Crossing

1. Determined by using Table 2 from the City's guidelines.
2. Street Average Daily Traffic (ADT) is in vehicles/day from data provided by the City of Minneapolis and previous counts done by Alliant in 2008.
3. Greenway Estimated Daily Traffic (EDT) is in users/day (bikes + peds) from data provided by the City of Minneapolis for September, 2008.
4. The 28th Street layout has been prepared and recommended by City of Minneapolis Staff.

James Avenue S Crossing

At the James Avenue S crossing, the daily Greenway user volume is higher than the street volume; therefore the recommended control is stop/yield signs facing the street. Stop signs facing the street are recommended as trees and shrubs could inhibit the yield sign stopping sight distance. The attached modified Example 3, Scenario 2 layout (from the City's guidelines) is recommended. Additionally, the existing northbound stop sign for the James Avenue S/Greenway intersection should be relocated closer to the Greenway, approximately 35 feet north of the current location. See the attached picture of the existing intersection for an illustration of the relocation. Adequate nighttime lighting was confirmed during a field investigation.

Irving Avenue S Crossing

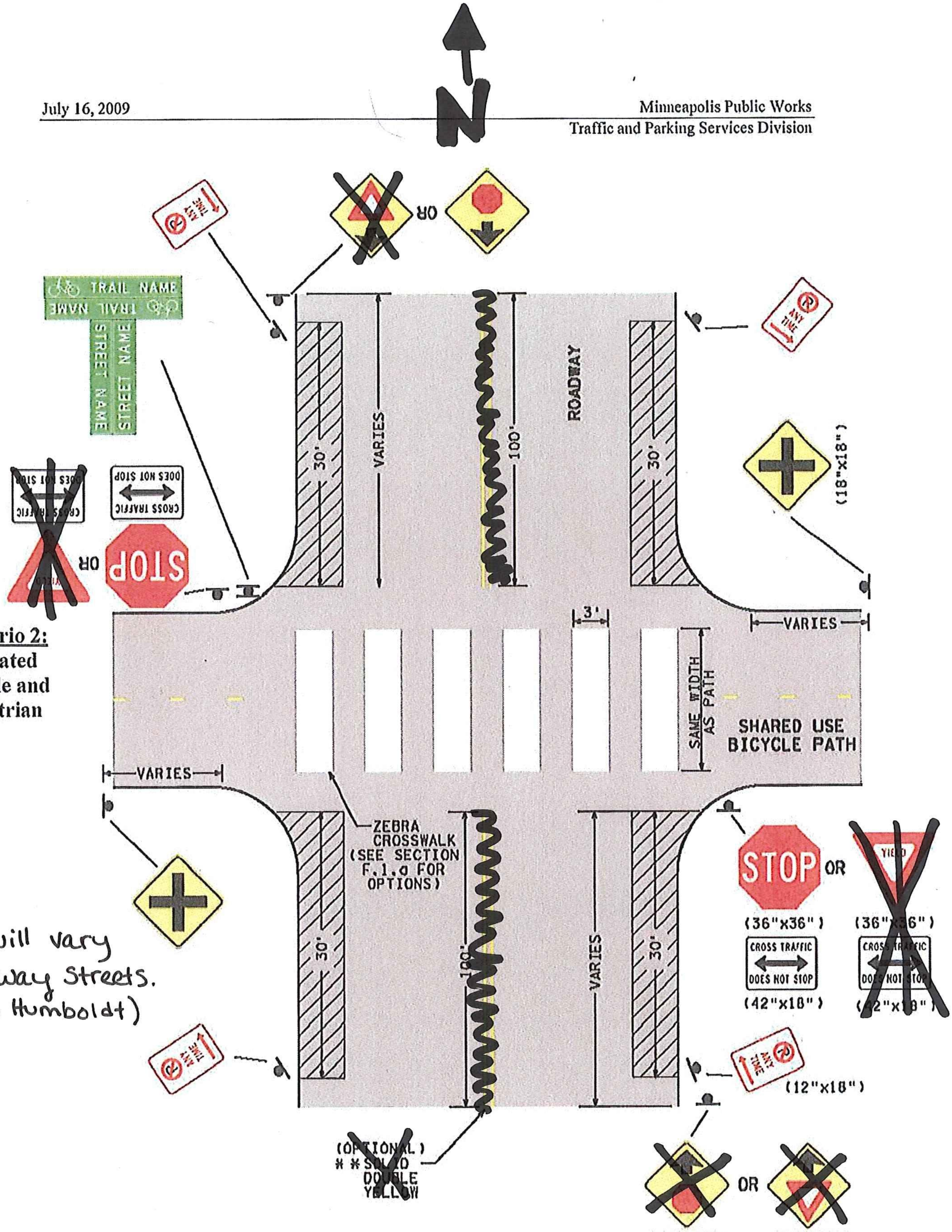
The daily Greenway user volume is higher than the street volume at the Irving Avenue S crossing; therefore the recommended control is stop/yield signs facing the street. Stop signs facing the street are recommended as trees and shrubs could inhibit the yield sign stopping sight distance. The attached modified Example 3, Scenario 2 layout (from the City's guidelines) is recommended. Irving Avenue S is a one-way northbound street in the area of the crossing, so southbound signing will not be needed. Additionally, the existing northbound stop sign for the Irving Avenue S/Greenway intersection should be relocated closer to the Greenway, approximately 35 feet north of the current location. See the attached picture of the existing intersection for an illustration of the relocation. Currently this crossing intersection is poorly lit and it is difficult to see trail users and signing/markings at night. It is recommended that overhead lighting be added in the area of the trail crossing. In the northeast corner of this crossing there is a green Northern States Power box that could possibly provide a lighting power connection.

Humboldt Avenue S Crossing
The attached modified Example 3, Scenario 2 layout (from the City's guidelines) is recommended where the Greenway is given at the Humboldt Avenue S crossing as the daily Greenway user volume is higher than the street volume. Stop signs facing the street are recommended as trees and shrubs could inhibit the yield sign stopping sight distance. Humboldt Avenue S is a one-way southbound street in the area of the crossing, so northbound signing will not be needed. The west side of this crossing is poorly lit during the nighttime hours. It is recommended that overhead lighting be installed on the west side of this crossing and the power connection could possibly be made through the existing emergency beacon on the trail just west of the Humboldt Avenue S crossing or through the existing lighting system.

5th Avenue S Crossing
At the 5th Avenue S crossing, the daily Greenway user volume is higher than the street volume. The modified layout shown in Example 3, Scenario 2 (attached) where the Greenway is given priority is recommended. Adequate stopping sight distance to install yield signs on 5th Avenue S was confirmed during a field investigation; therefore yield signs facing the street are recommended. Adequate street lighting exists on 5th Avenue S to provide for safe nighttime operations.

E 28th Street Crossing
This crossing currently has an overhead yellow flasher for both directions of E 28th Street that is pushbutton activated by trail users. The concern is E 28th Street is a four-lane road (two lanes in each direction) carrying an ADT of 7,267 vehicles per day at the location of this crossing. The existing 4-lane roadway is considered a double threat for bicycles and pedestrians using the crossing as there are two lanes of approaching traffic in each direction. The city has recommended a layout for E 28th Street (attached) where the roadway is narrowed down to two lanes (one lane in each direction) through on-street striping modifications. It is noted that a two-lane roadway will be able to accommodate the existing ADT. By reducing E 28th Street to two lanes at the trail crossing, the area of potential interaction between trail users and vehicles is reduced by half and speeds on E 28th Street will decrease, resulting in enhanced safety for the trail users. After the roadway modifications are implemented, the City will monitor the operations and safety of the crossing to determine if further action is needed.

Scenario 2:
Separated Bicycle and Pedestrian Paths



*Layout will vary for one-way streets. (Irving & Humboldt)

** COLLECTOR ROADWAYS OR HIGHER

Example 3. Mid-Block Crossing Typical Traffic Control (Shared-Use Path Has Priority) Cont'd

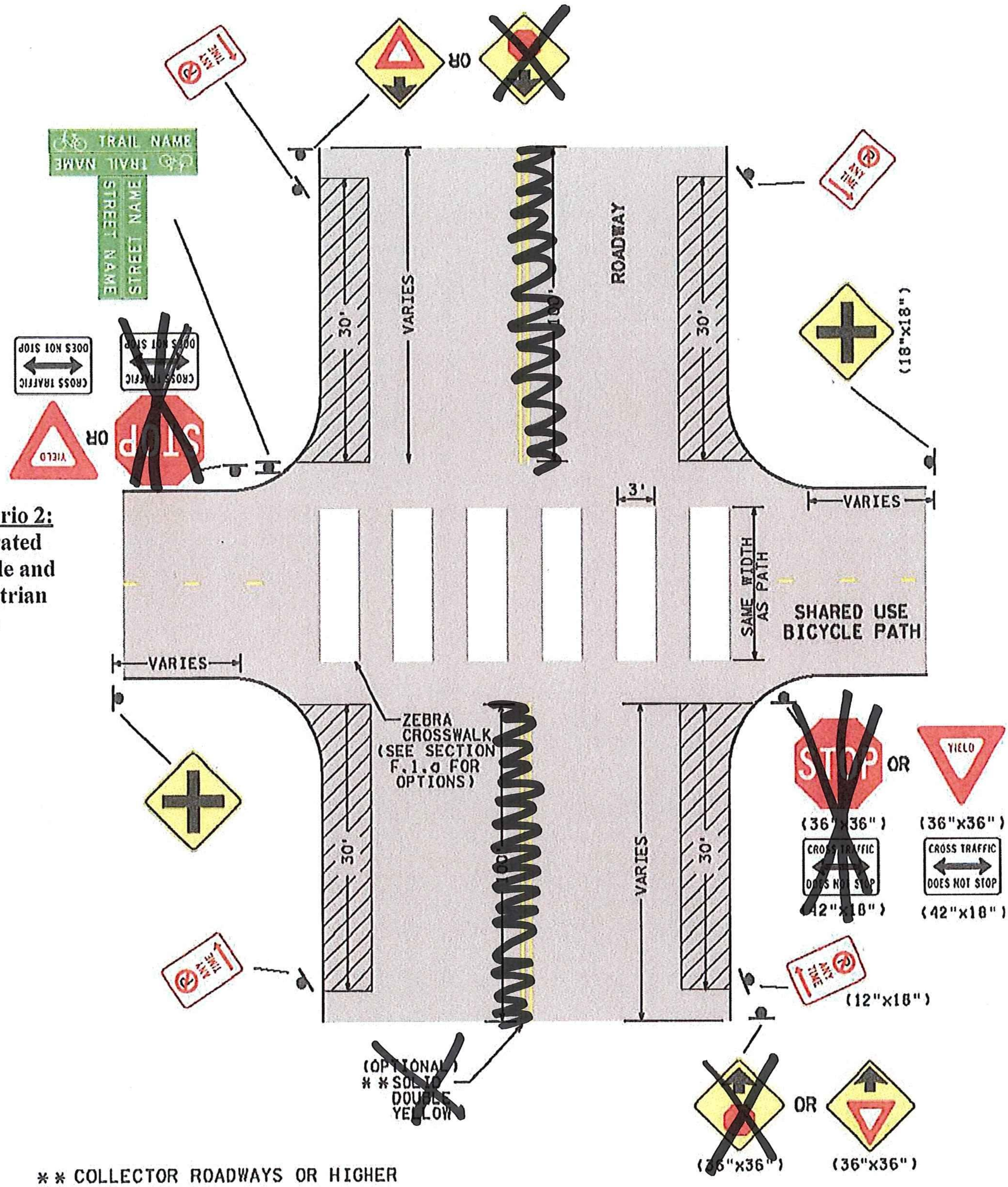
James/Irving/Humboldt Crossings

North

James Ave. S / Midtown Greenway NB STOP Sign Relocation

Irving Ave. S / Midtown Greenway NB STOP Sign Relocation

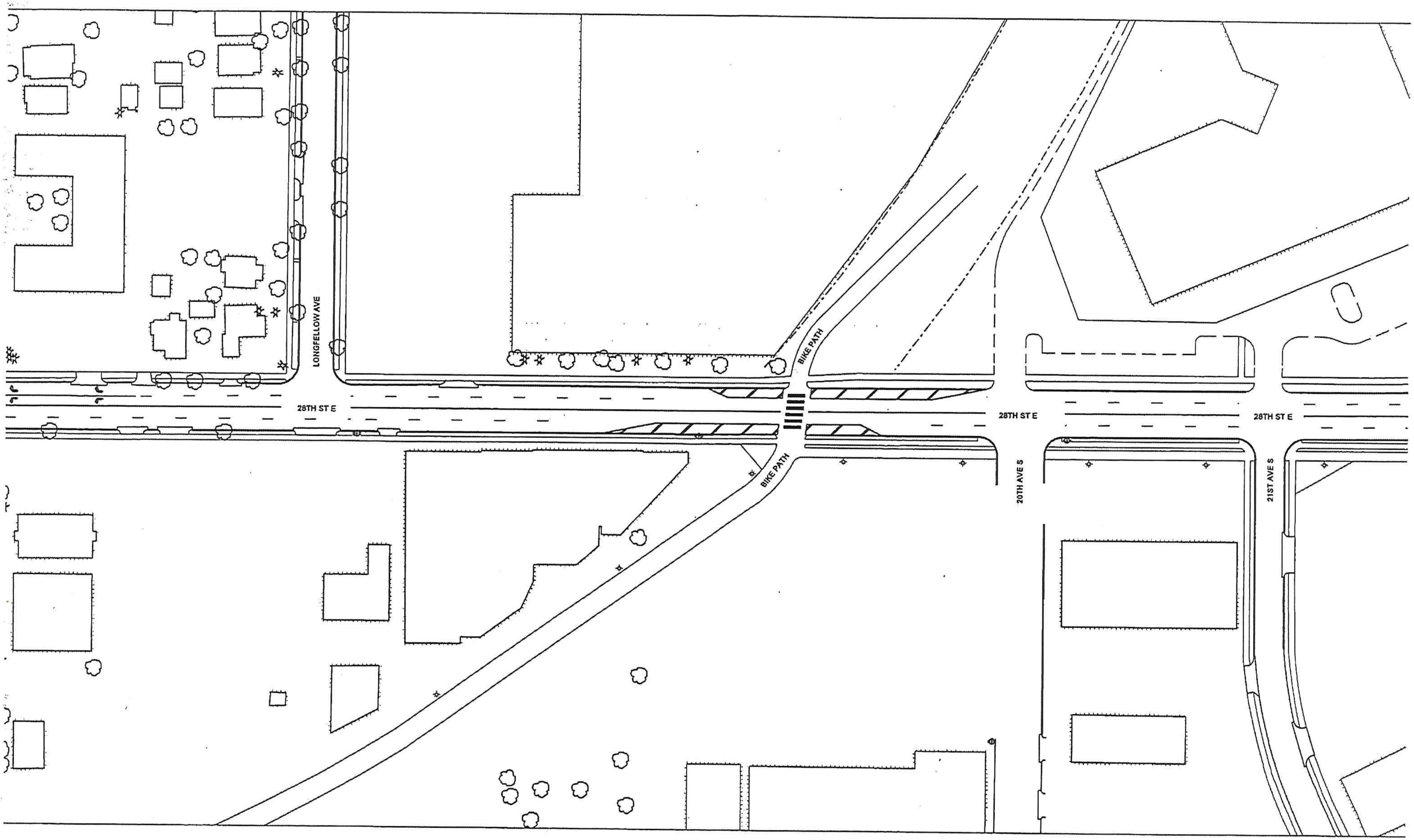
Scenario 2: Separated Bicycle and Pedestrian Paths



** COLLECTOR ROADWAYS OR HIGHER

Example 3. Mid-Block Crossing Typical Traffic Control (Shared-Use Path Has Priority) Cont'd

5th Ave. Crossing


LONGFELLOW AVE
BIKE PATH
28TH ST E
28TH ST E
28TH ST E
BIKE PATH
20TH AVE S
21ST AVE S

TITLE

Counting Bicyclists with Pneumatic Tube Counters on Shared Roadways

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ABSTRACT

Local governments investing in bicycle infrastructure often lack good methods for documenting bicyclist volumes, an essential metric for evaluating the usage and relative safety of bicycle infrastructure. This study determines the accuracy of using portable pneumatic tube counters to simultaneously conduct short-term counts of both bicyclists and motor vehicles.

INTRODUCTION

Transportation agencies conduct systematic motor vehicle counts to estimate Annual Average Daily Traffic (AADT) volumes for use in planning and engineering decisions. By contrast, bicycle traffic counts are non-existent in many jurisdictions. As a result, planning and engineering decisions, as well as usage and safety studies, are made without reliable bicyclist data. Given limited budgets, extensive bicycle counting programs are difficult to fund, but this paper explores how local governments can integrate bicycle counting into an existing traffic counting program in a cost effective manner.

Many papers have explored the accuracy of various bicycle counting equipment, but few have included accuracy tests of a technology often used for motor vehicle counts: pneumatic tubes. There are two types of tube counters: bicycle-specific counters (BSC), that only count bicyclists, and general purpose counters (GPC) that attempt to count bicyclists and motor vehicles. Studies of BSCs show relatively high accuracy, while studies of GPCs throw doubt on their accuracy in mixed traffic conditions[1, 2]. This paper examines the accuracy of both types of tube counters.

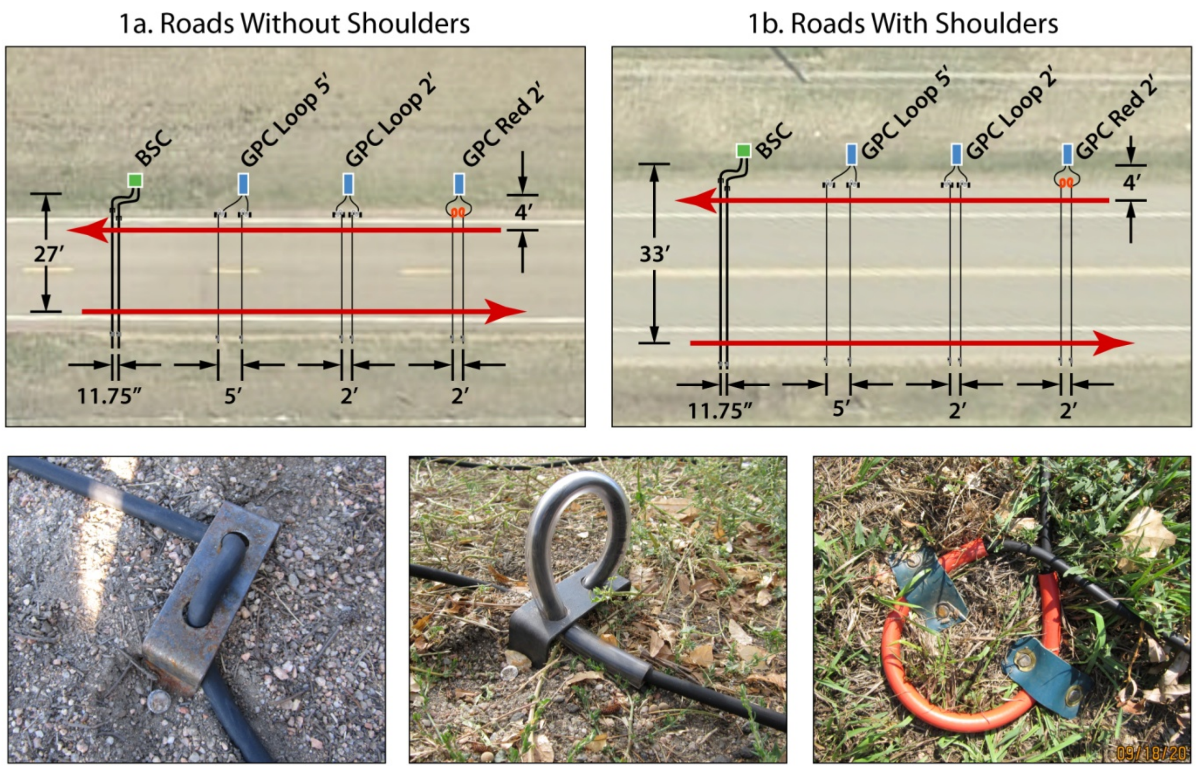
LITERATURE REVIEW

For decades, agencies have used pneumatic tube counters to count bicyclists with the same tubes used to count motorized traffic [3]. Before the development of more advanced sorting algorithms, pneumatic tubes could only be used to count bicyclists on bicycle-only facilities such as off-street paths or, to some extent, the shoulders of roads [4]. In recent years, more companies have claimed that their pneumatic tube counters are capable of counting bicyclists and motor vehicles separately in mixed traffic [5, 6], while other products focus only on counting bicyclists in mixed traffic [7]. The use of tubes is common, and they are listed as available technology for bicycle counting in several references [8-10].

Despite the common use of such technologies, little literature exists on their accuracy. A Norwegian study reports accuracy of 95% for tube counters that count bicyclists only (Eco-Counter, Lannion, France) and 70% to 75% for technology counting motorists and bicyclists separately (MetroCount, Freemantle, Australia) [2]. Studies from New Zealand show varying results on the accuracy of counting bicyclists [11]. The most recent found that the accuracy of MetroCount tube counters for counting bicyclists varied from 14% to 100% and averaged 62% [1]. The report recommends counting the shoulder or bicycle lane separately from the motor vehicle lane to minimize counting error when using MetroCount 5600. Despite such warnings, agencies and consultants use this product and similar motor vehicle tube counters to count bicyclists and motor vehicles on roadways. This paper documents how this can be done accurately while minimizing cost.

DATA

This study evaluates the two types of pneumatic tube counters that can be used to count bicyclists: BSCs, which are represented by Eco-Counter, and GPCs, which are represented by MetroCount. Data used in this paper were generated in 2012 when county staff studied three GPCs and one BSC at 12 locations (see Figure 1). The GPCs were used with 'bicycle' tubes, whose thinner tube wall increases the likelihood of counting bicyclists. The BSC uses a proprietary thicker tube with a special lining that amplifies the air pulse generated by bicyclists' wheels.



1c. Metal Bracket- used to secure the BSC's tubes

1d. Vinyl Tubing + Metal Bracket- used to secure GPC Loop 5' and GPC Loop 2'

1e. Red Rubber Hose- used to secure GPC Red 2'

Figure 1. Station Layouts and Attachment Methods Tested

Two of the GPCs' tubes were anchored to the road by inserting them through an 18" section of clear vinyl tubing and threading this tube through a metal bracket. This allowed the tubes to be secured tightly without pinching them, which obstructs the air pulse bicyclists generate. The tubes for these counters were spaced at 2' and 5' apart (GPC Loop 2' and GPC Loop 5'). The third set of tubes was anchored to the road by sliding them through an 18" section of red rubber hose and strapping this hose to the ground; these tubes were spaced 2' apart (GPC Red 2'). The BSC's thicker tubes were not susceptible to kinking; they were anchored with metal brackets spaced 11.75" apart, per the manufacturer's instructions. The natural bicycle traffic at these locations was augmented with volunteers riding in laps over the tubes at speeds ranging from 10 to 22 mph. Staff observed and manually recorded a combined total of 2,184 bicycle events during 17.25 hours of observation. On a few occasions, tubes were discovered to be defective; these datasets were discarded.

METHODS

There are three steps in the analysis. First, the data were split into three groups based on the average distance from the counter bicyclists rode over the tubes. Second, a new classification scheme was written to improve the traffic analysis software's accuracy. Third, the weighted average accuracy was calculated for all attachment methods studied and the weighted 95% confidence intervals and correction factors were calculated for the most accurate attachment methods.

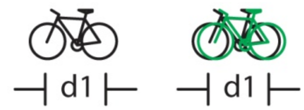
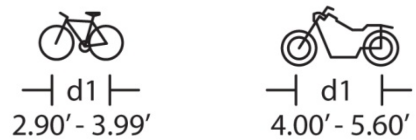
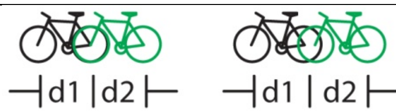
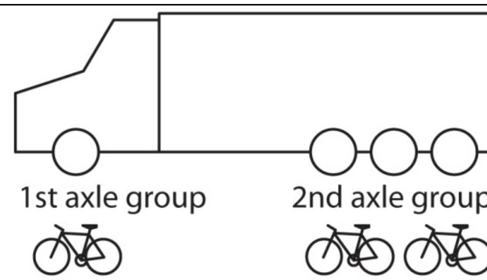
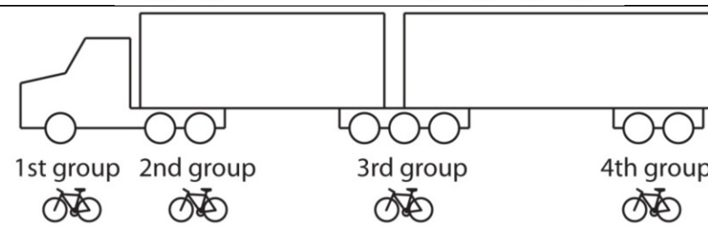
Initial work with the GPCs indicated that they were more accurate when bicyclists crossed the tubes close to the counter. It was posited that the air pulses generated by bicyclists' wheels weakened as they traveled through the tubes to the counter. This led to the creation of three groups for the data: the 4' group, the 27' group and the 33' group. The 4' group includes bicyclists riding over the tubes on the same side of the road as the counter, while the 27' and 33' groups include bicyclists riding over the tubes on the opposite side of the road from the counter, where shoulders were not and were present, respectively (see Figure 1).

Classification Schemes

Traffic analysis software organizes axle hits recorded by a counter into vehicles and then uses a classification scheme to sort the vehicles into different classes. A classification scheme is a set of rules that allow the software to differentiate between different classes of vehicles based on the number of axles, the distance between axles, and the number of axle groups in each vehicle. In typical classification schemes, the distance between the first and second axle is termed 'd1'; between the second and third axle: 'd2,' etc. Axles are considered part of the same group if they are less than 5.4' apart. If a vehicle does not fit the rules for any vehicle class, it falls into an 'unclassifiable' class.

Boulder County Classification Scheme

Classification schemes are generally written for motor vehicles; therefore, their ability to accurately classify bicyclists is limited. Existing schemes misclassify groups of bicyclists as trucks or are unable to classify them at all, reducing the counter's apparent accuracy. For this study, the authors created a new classification scheme, the Boulder County Scheme (BOCO). Based on the widely available ARX Cycle Scheme, BOCO revises the rules for truck classes to exclude groups of bicyclists and creates new classes for groups of bicyclists (see Table 1).

Table 1. Boulder County Classification Scheme (BOCO)		
Problem	**Solution**	**Illustration**
Two bicyclists riding side by side are only counted as one bicyclist.	No tube counter can distinguish between one bicyclist and two bicyclists riding side by side. This results in an unavoidable undercount.	
The occasional larger bicycle is classified as a motorcycle.	The d1 cut-off between the bicycle and motorcycle classes was increased to 4' to correctly classify these vehicles.	
Two bicyclists riding offset fall into the unclassifiable class.	A new two-bicycle class was created to include bicyclists riding in these configurations.	
Two bicyclists drafting fall into the unclassifiable class.	A new bicycle class was created to include bicyclists riding in this configuration.	
Multiple bicyclists riding in two groups were interpreted as one truck.	A truck class was edited to exclude bicyclists riding in two groups. New multi-bicycle classes were created to correctly classify bicyclists riding in two groups.	
Bicyclists riding near each other in three or four axle groups are classified as trucks.	Heavy truck classes were edited to exclude groups of bicyclists. New bicycle classes were created to include groups of three and four bicyclists.	

The third step in the analysis was to calculate the weighted average accuracy for the different attachment methods and classification schemes. Then, 95% confidence intervals and correction factors were calculated for the most accurate attachment methods (see Table 2).

Table 2: Formulas Used in Data Analysis	
Equation	**Definition of Variables**
$\bar{x}_w = \sum (x * \frac{f}{n})$	$\bar{x}_w$ = weighted average accuracy x = observed accuracy for a 15 minute bin f = number of bicycle events in a 15 minute bin n = total number of bicycle events in the distance group
$CI_{95\%} = Z_{\frac{a}{2}} * \sum \sqrt{n}$	$CI_{95\%}$ = weighted 95% confidence interval Z = z score a = critical value for the z score n = total number of bicycle events in the distance group
$cf = \frac{1}{\bar{x}_w}$	cf = correction factor $\bar{x}_w$ = weighted average accuracy

RESULTS

Table 3 shows the observed accuracy recorded by the GPCs using the ARX Cycle and BOCO schemes for the three distance groups and three attachment methods tested. The BSC's classification scheme is proprietary, so only its off-the-shelf accuracy was tested. The BOCO scheme's accuracy was higher than the ARX Cycle scheme's accuracy for every attachment method and distance group tested.

Table 3: Summary of Data Collected					
Attachment Method	**ARX Cycle Scheme $\bar{x}_w$**	**BOCO Scheme $\bar{x}_w$**	**BSC $\bar{x}_w$**	**15 minute bins**	**bicycle events**
4' group					
GPC Loop 2'	72.29%	94.95%	-	69	1,090
GPC Loop 5'	67.50%	94.68%	-	63	1,036
GPC Red 2'	66.57%	94.06%	-	43	724
BSC	-	-	94.59%	69	1,090
27' group					
GPC Loop 2'	38.77%	47.12%	-	29	524
GPC Loop 5'	43.18%	54.72%	-	23	472
GPC Red 2'	38.32%	44.32%	-	14	328
BSC	-	-	94.80%	29	524
33' group					
GPC Loop 2'	49.15%	54.92%	-	40	570
GPC Loop 5'	50.87%	60.35%	-	40	570
GPC Red 2'	48.30%	51.90%	-	29	394
BSC	-	-	56.81%	35	521

From Table 3, the GPC Loop 5’ attachment method and the BSC were selected for further analysis. The BSC was selected because it was the only bicycle-specific counter tested. The GPC Loop 5’ attachment method was selected for several reasons. In both the 27’ and 33’ groups its accuracy was the highest among the GPCs’ attachment methods. Second, the accuracy of all three GPCs’ attachment methods was almost identical in the 4’ group; isolating this distance group did not favor any one over another. Third, setting the tubes at 5’ apart instead of 2’ reduces the error that results from small variations in field installation of the tubes. If the tubes are set at 23” apart instead of 24”, this inflates motor vehicle and bicycle wheelbases, axle spacings and speeds by 4.3%. However, if the tubes are set at 59” instead of 60”, this only inflates said measurements by 1.7%.

Table 4 shows the weighted average accuracies and weighted 95% confidence intervals for the BSC and the GPC Loop 5’ attachment method, displaying the GPCs’ results for both the ARX Cycle and BOCO schemes.

Table 4. Accuracies, Confidence Intervals and Correction Factors

Distance Group	GPC Loop 5' (ARX Cycle)			GPC Loop 5' (BOCO)			BSC		
	$\bar{x}_W$	$CI_{95\%}$	*cf*	$\bar{x}_W$	$CI_{95\%}$	*cf*	$\bar{x}_W$	$CI_{95\%}$	*cf*
4’ group	67.50%	±7.54%	1.48	94.68%	±2.68%	1.06	94.59%	±5.32%	1.06
27’ group	43.18%	±8.84%	2.32	54.72%	±9.85%	1.83	94.80%	±6.02%	1.05
33’ group	50.87%	±9.35%	1.97	60.35%	±8.95%	1.66	56.81%	±9.95%	1.76

The data from Table 4 are graphed in Figure 2. The BSC’s high accuracy up to the 27’ group is clearly visible, while the GPC seems to experience a more gradual decline as the distance increases. All counters show wider confidence intervals at greater distances.

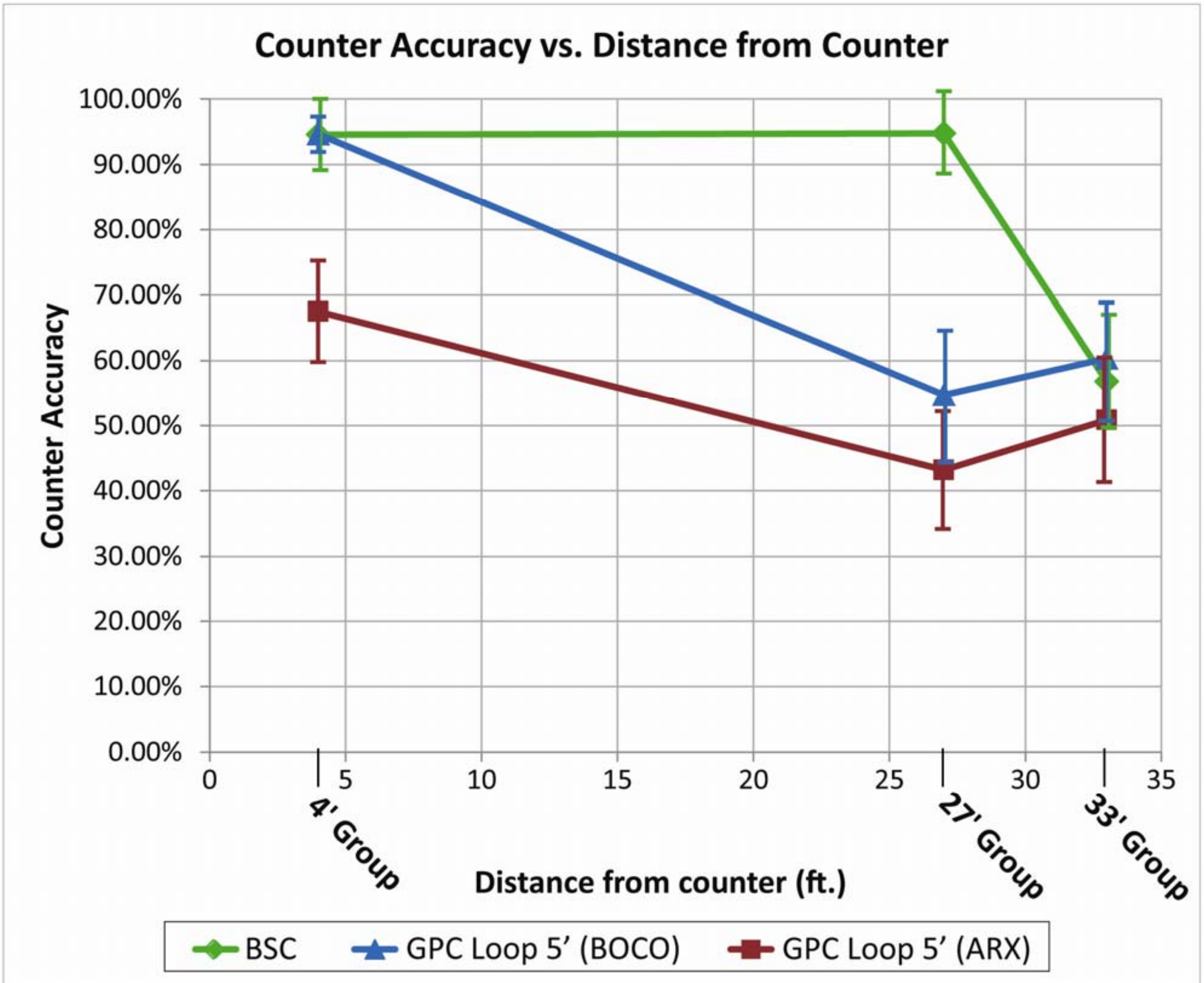


Figure 2. Accuracies and 95% Confidence Intervals of Selected Attachment Methods

CONCLUSION

The BSC proved very reliable and accurate when counting bicyclists striking the tubes up to 27' away from the counter. For both the 4' and 27' groups, its weighted average accuracy was between 94% and 95%. However, in the 33' group its accuracy fell to 56.81%. The major advantage of the BSC is that it can accurately count bicyclists on both sides of a two lane road with no aftermarket modifications. However, if the road to be counted is wider than 27', caution must be used due to the observed rapid decline in accuracy between the 27' and 33' groups. Using BSCs to count bicyclists can lead to a duplication of efforts if motor vehicle counters are also used at the same locations.

The GPCs' accuracy and reliability proved highly variable depending on the attachment method and classification scheme used. However, when the attachment method and custom classification scheme outlined in this paper were used, the GPC proved highly accurate and reliable in the 4' group, counting a weighted average of 94.68% of bicyclists. The GPC's accuracy declined to 54.72% and 60.35% in the 27' and 33' groups, respectively. Two significant obstacles with the GPC's equipment and software need to be overcome in order to accurately count bicyclists. First, an attachment method that can secure the tubes without pinching them is essential. This study indicates that routing the bicycle tubes through a section of vinyl tubing anchored to the ground is one suitable attachment method. Second, the authors found that bicyclists travelling in groups cannot be accurately counted using existing classification schemes. As part of this study, the BOCO classification scheme was written to differentiate between groups of bicyclists and trucks. This scheme significantly outperformed the ARX Cycle scheme for every attachment method and distance group tested.

In order to obtain highly accurate bicyclist data with small margins for error using GPCs, one counter needs to be used on each side of the road. This effort duplication ensures that each direction of bicycle traffic falls into a 4' distance group. However, if only one counter can be used per location, one direction of bicycle traffic will have a larger margin of error due to the wider confidence interval in the 27' and 33' distance groups.

No counter tested counted every bicyclist; therefore, correction factors were computed to correct systematic bias in the counts. Recorded bicycle counts need to be separated by direction or by different distance groups because of the varying accuracies and the need to use different correction factors.

The recommended type and number of counters to be used depends on the data required. If only bicyclist data are needed, a single bicycle-specific counter can be used with no aftermarket modifications to accurately count bicyclists travelling in both directions on roads up to 27' wide. However, if bicyclist and motor vehicle traffic data are required, one or two general purpose counters, used with bicycle tubes, the modified attachment method and the classification scheme outlined in this paper, are recommended.

AREAS FOR FURTHER STUDY

Additional studies would provide more insight into the reliability and adaptability of the approaches detailed in this paper. First, as only three distances to the counter were studied, it is premature to develop a linear regression model capable of calculating accuracy based on distance. Second, anecdotal evidence indicates that when a car passed a bicyclist over the tubes the counter was occasionally unable to correctly interpret the resulting burst of axle hits. The authors hypothesize that at some volume of traffic, this could occur too frequently for combined counts to be accurate. However, this study was limited to understanding and minimizing undercounts resulting from attachment methods and classification schemes.

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